U.S. Army Corps of Engineers
Portland District

Hydroacoustic Evaluation of Downstream Fish Passage at John Day Dam in 2000

FINAL REPORT

November 2001

Prepared by
Battelle's Pacific Northwest Division
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Executive Summary

The hydroacoustic study at John Day Dam in 2000 was designed to address two objectives. The first objective was to estimate downstream juvenile salmon passage rates through the turbines, bypass system, and spill, and in relation to discharge. The second objective was to estimate the differences in routes and timing of juvenile salmon passage between two spill regimes. In support of the objectives, split-beam hydroacoustic techniques were applied at each type of route to evaluate the influence of trajectory, speed, and size on fish detectability in single-beam systems. Battelle scientists collected data at John Day Dam from 6 June through 7 July, 2000.

Spill treatments were either 0% daytime spill or 30% daytime spill. Both treatments included nighttime spill at 60% of total river flow. Treatment effects were significant for fish passage efficiency, spill efficiency, and spill effectiveness, but not for fish guidance efficiency. The 30% daytime spill regime was more effective at passing fish than the 60% nighttime spill of either treatment. However, a high degree of uncertainty existed in estimates of both spillway passage and fish guidance efficiency because transducer sampling locations were not optimum. Thus, the influence of spill treatments on FGE could not be determined with certainty. This study provided a basis to rectify outstanding deficiencies in transducer placement for monitoring fish passage at John Day Dam.

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1.0 Introduction

1.1 Background

The U.S. Army Corps of Engineers (Corps) is committed to increasing survival rates for fish passing its hydroelectric projects on the Columbia River. At John Day Dam, this strategy has entailed the use of spill, and the design and prototype testing of a turbine intake extended-length submerged bar screen (ESBS) juvenile bypass system (JBS). Surface flow bypass options are still under consideration.

Basic information on juvenile fish passage is necessary for several reasons. The first step to improving conditions for migrants is to determine the current conditions. Such base line data are necessary in the evaluation of any recommendations or changes that are made in the future. Additionally, without detailed information on fish behavior and distributions across space and time, successful improvements in FPE are very unlikely. Giorgi and Stevenson (1995) reviewed studies on juvenile salmon distribution and behavior at Corps projects in the lower Columbia River and concluded that although such studies have been conducted for over 15 years they provide little information useful in the design of surface collectors. The past studies were focused on such items as estimation of passage through few routes, presence or absence data, intake screen guidance efficiency, or spill management. For surface collection designs we need to know what is going on upstream of the dam, prior to where a fish is forced to dive, or is holding, and exactly how and why fish pass where they do. Efforts to collect this more comprehensive information with hydroacoustics began in 1997 (BioSonics, 1998).

Radio telemetry studies have reported passage delays of several hours in the immediate forebay of John Day Dam during low spill (Sheer et al., 1997). This suggests that, under certain conditions, passage improvements are warranted, and these fish may be available for surface collection. Radio telemetry is necessarily limited to collecting information on a relatively small number of individuals that represent the fish population at large. In contrast, the hydroacoustic techniques which Battelle used in this study allow collection of information on a relativ+ely large number of individuals. Together, the techniques reveal a great deal about the behavior of juvenile salmon in the forebay of the dam and while passing the projects (Johnson et al., 2000).

Spill at John Day Dam can cause the total dissolved gas concentration to quickly exceed levels harmful to fish. Therefore spill is limited, although flow deflectors have been installed that allow greater spill levels to be achieved before reaching excessive total dissolved gas concentrations. In order to optimize fish passage at John Day Dam, a balance must be struck between spill levels, intake screen guidance efficiency, and surface bypass. Accurate passage efficiency estimates for all routes are necessary to estimate project survival and thereby evaluate any operational or fish facility modifications.

1.2 Goal and Objectives

The goal of this study was to collect critical information for the Corps' spill passage program to optimize project passage. For this study, the goal was to determine if downstream migrants would benefit from spilling 30% of the river during the day at John Day Dam. Specific objectives for the 2000 study were to:

- estimate the proportion of juvenile salmon passing the dam through each passage route, and in relation to discharge

- estimate differences in rates and timing of fish passage between two spill regimes

1.3 Study Site Description

John Day Dam, located at Columbia River mile 215.6, includes a navigation lock, a spillway with 20 bays (numbered north to south), and a 1975 ft long powerhouse comprised of 16 turbines and 4 skeleton bays (Figure 1). Standard length submerged traveling screens (STS) are in all units, with a juvenile fish facility located on the Oregon shore. Turbine units are numbered 1-20 from south to north. Spill bays are numbered from north to south. Each unit is divided into three intakes, identified as A, B, and C, beginning from the north.

The historical river channel, or thalweg, at John Day Dam passes through the north end of the powerhouse, near the intersection with the spillway (Figure 2). The majority of flow in the reservoir above the dam is through the thalweg. This bulk flow following the bathymetric contours below may have implications for fish passage patterns with the bulk of migrants following the thalweg (Johnson and Dauble 1995). The forebay environment is one factor that makes fish passage at each hydroelectric facility unique.

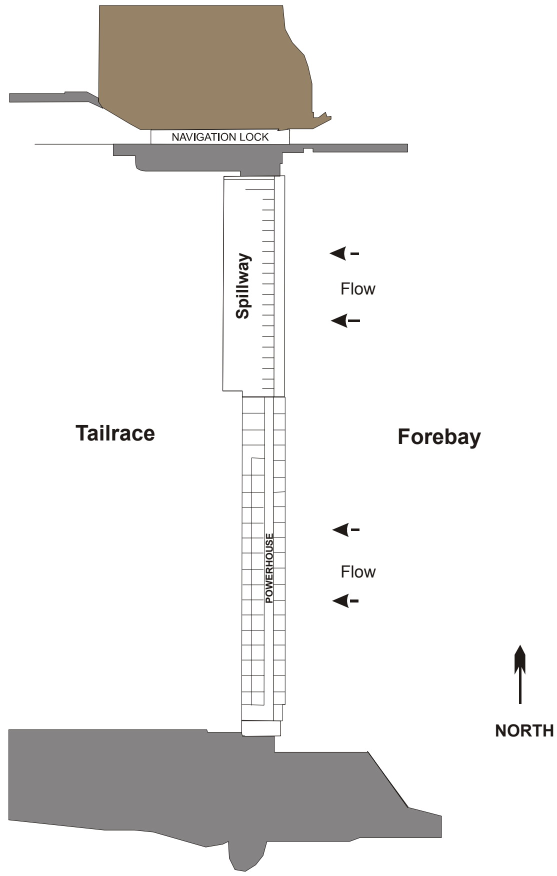


Figure 1. Plan view of John Day Dam.

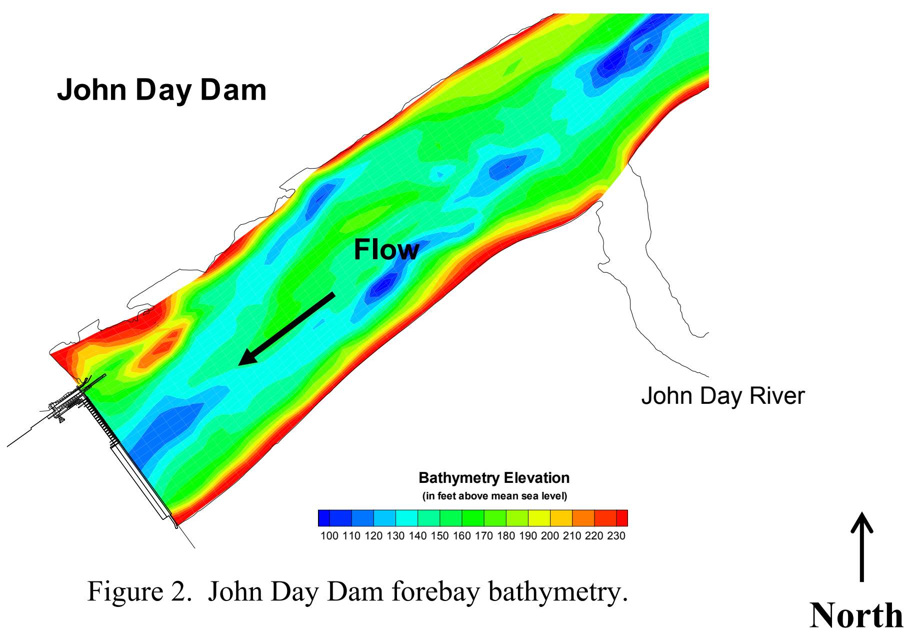


Figure 2. John Day Dam forebay bathymetry.

2.0 Methods

2.1 Study Design and Study Periods

Spill was manipulated for the purpose of this study. Treatments were either 0% daytime spill or 30% daytime spill. Both treatments included nighttime spill at 60% of total river flow. A randomized block design was used with 6-day blocks. Five complete blocks of data were collected and analyzed for this study. A treatment was in place for 3 days and was assigned to either the first or last half of a block. Each treatment day began at 0600 h and ended at 0559 h. Nighttime extended from 1900 h through 0559 h. Data collection occurred from 6 June through 7 July, 2000.

2.2 Hydroacoustic Systems and Transducer Deployments

A combination of single- and split-beam deployments were used to estimate fish passage through the powerhouse and spillway. This approach uses the acoustic screen model to determine passage rates. Single-beam transducers were deployed to sample fish passage at the spillway and powerhouse. A split-beam transducer was deployed to characterize the physical and acoustic conditions at one location of each deployment type. The characteristics of fish detected by split-beams were used to estimate the effective beam width used to expand single-beam fish counts to passage numbers, and to assess assumptions of the model.

Transducer sampling volumes were placed so that ambiguity in fish passage routes and the potential for multiple detections was minimized. Figure 3 presents a plan view of all sampling locations at John Day Dam in 2000. Single-beam data collection used four BioSonics ES2000™ systems among the locations shown, with BioSonics DT6000™ split-beam systems deployed at one location for the spill, as well as one each, in-turbine, uplooking, and downlooking. All single-beam transducers were 420 kHz and had circular elements. All split-beam transducers were 200 kHz and had circular elements. Single-beam transducers were multiplexed; split-beam transducers were not.

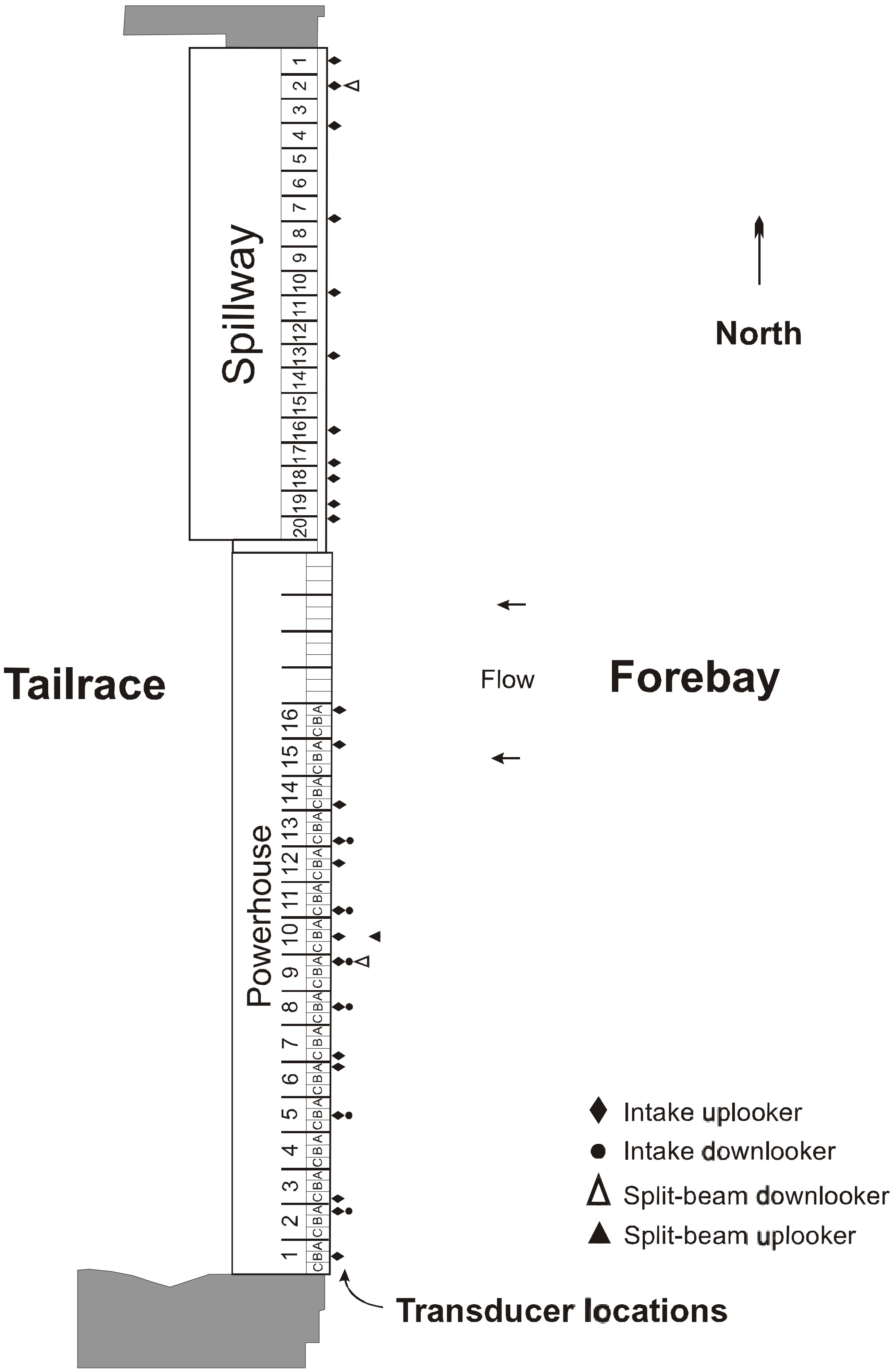


Figure 3. John Day Dam transducer deployments. The Washington shore is at the top of the page; the Oregon shore is at the bottom.

2.2.1 Intakes

Intake transducers were sampled for 2.5 minutes 4 times per hour, or a total of 10 min for every hr. One randomly selected intake of each of the 16 turbine units (intake A, B, or C) was monitored, except Unit 4, which was not scheduled to run during the study. In addition, transducers were randomly positioned from the center of the unit, in either a north (n) or south (s) location within the intake. The exact position was determined by trashrack drain holes to which they were attached. The powerhouse sampling locations (unit-intake-position) were: 1Bn, 2As, 3Cs, 5Bs, 6An, 7Cs, 8Bn, 9As, 10Bs, 11Cn, 12Bn, 13Cs, 14Cn, 15An, and 16As. A split-beam transducer for these uplookers was located at slot 9A. Sampling locations at the downlooker transducer locations (unit-intake-position) were: 2As, 5Bs, 8Bn, 9As, 11Cn, and 13Cs. A split-beam downlooker was located at slot 10B.

The deployment combination of up- and downlooking transducers attached to the inside of the trashrack has been used to estimate fish guidance efficiency (FGE) successfully at other dams in the region. Notable was a similar deployment used with reasonable success for estimating FGE at an extended-length submersible bar screen (ESBS) at John Day Dam (Ploskey and Carlson 1999). We used 6° single-beam transducers for sampling the powerhouse. One 6° split-beam transducer was used for duplicate sampling at one powerhouse location. Because of trash raking practices, transducers were mounted from drain holes on the inside of the trashrack. These transducers were aimed upward about 30° downstream (perpendicular to the intake ceiling). The pulse repetition rate for all turbine transducers was 12 pings per second (pps) (Figure 4).

2.2.2 Spillway

Passage through the spillway was monitored using new spillway mounts that were designed, fabricated, and installed in 2000. These mounts moved the transducers closer to the tainter gate than the previously used parapet wall mounts. This decision was based on data and recommendations presented in Ploskey et al. (2000). Spillway transducers sampled for 2.5 minutes 4 times per hour, or a total of 10 min for every hr. Eleven spill bays were monitored using 12° single-beam transducers deployed on pole mounts that were bolted to the upstream stop log slot wall. One randomly selected spill bay was monitored using a 6° split-beam system. Each transducer was offset randomly in a north, middle, or south to account for possible non-uniform horizontal distribution through the spill bays. Spillway sampling locations (bay) were: 1m, 2m, 4n, 7s, 10s, 13m, 16m, 17s, 18m, 19m, and 20n. The split-beam transducer was located at Bay 2. All transducers were mounted on the bottom of the pole and aimed downward 8° downstream (Figure 5). The pulse repetition rate at the spillway was 24 pps.

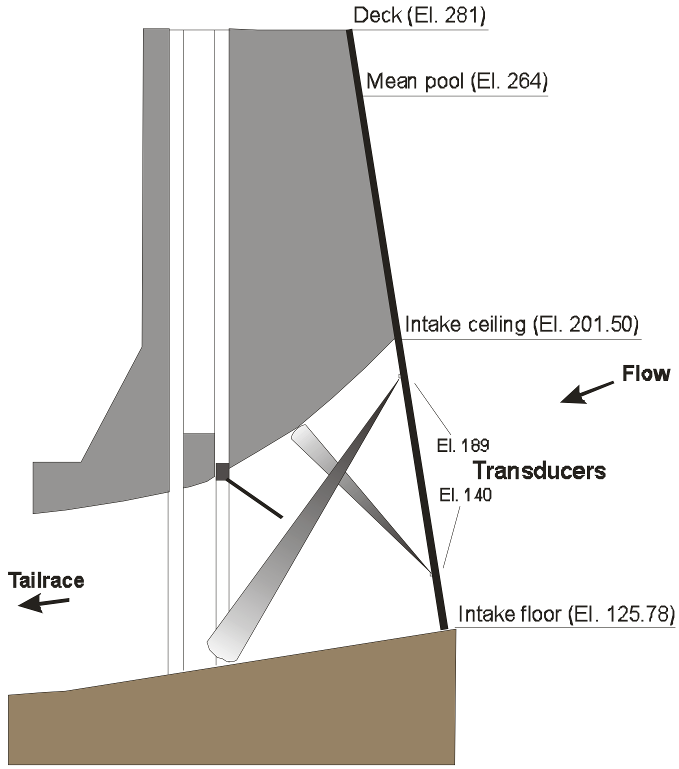


Figure 4. Turbine intake transducer deployments in cross-section. Total intake passage was determined from the uplooker, as in previous hydroacoustic studies.

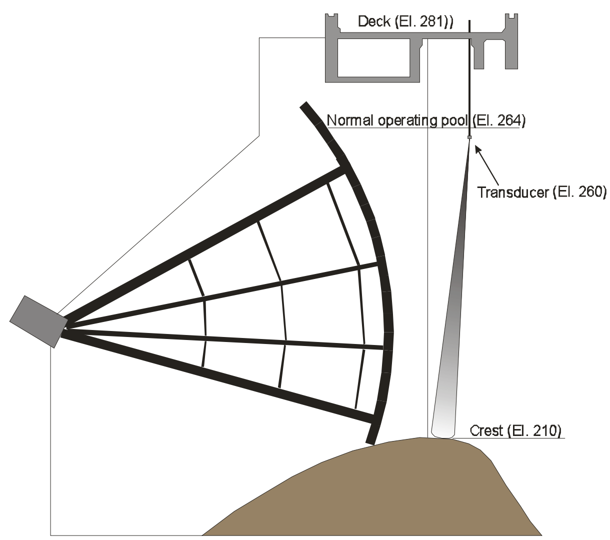


Figure 5. Spill bay transducer deployment in cross section.

2.3 Detectability

Passage rate estimates from fish trace data files were produced using the acoustic screen model, an echo counting procedure by which passage rates are estimated from a fixed transducer sample location. The technique relies on detection of echoes from fish that form an identifiable trace, or track, of echoes through space and time. Because track formation is related to the trajectory and speed of fish moving through a transducers' sampling volume, deployment characteristics can greatly alter detectability. The acoustic screen model is limited by noise sources that obscure fish traces, such as electrical, wind-generated turbulence, and reverberation from structures. Johnson (2000) provides a description of the acoustic screen model and an assessment of its assumptions. Some critical parameters in the acoustic screen model are the effective beam angle in the echo counting process and the "number of echoes" criterion in the trace formation process.

2.3.1 Fish Velocities and Target Strengths

Because mean fish velocities and target strengths differed (ANOVA, $p < 0.01$) between day and night at the spill bays (Table 1), detectability was computed for day and night separately. Too few tracks were identified during a number of opening levels to allow split-beam data to characterize differences in detectability among spill gate openings. This was a result of deploying the split-beam transducer at a spill bay that never attained the higher spillgate openings. At the powerhouse, operations were relatively constant, and fewer fish tracks were identified. The number of fish tracks identified in split-beam data was not sufficient to differentiate velocities among diel periods or by turbine operations. Detectability at the intakes with respect to operations was treated as being constant through time, as flow through the turbine units usually varied only slightly.

Mean target strengths were determined for each deployment type by range for fish tracks identified in split-beam data (Table 1). Mean target strength was a direct output of the split-beam data, as described in Appendix A:1. Spill data were divided into day and night periods to be consistent with analyses of mean velocity.

This argument for modeling day and night differently assumes that fish behavior is driving differences in detectability. Entrance hydraulics of a spill gate with a certain amount of head is not expected to change significantly. However, fish trajectory, velocity, and orientation (fish aspect to the sonar), however, may be different enough to alter detectability. Evidence of this is shown by differences in fish velocities and apparent target strength (fish aspect) by this study. Further differences in day/night fish behavior is inferred from radio tag studies where smolts, particularly subyearling chinook, may hold in the forebay during the day and not during night (Poe, Anglea, and Giorgi, 2001).

Table 1. Mean target strength (dB) and velocity (m/s) by range for each deployment type and day/night period.

Range (m)	Intake uplooker TS (Velocity)	Intake downlooker TS (Velocity)	Spill Day TS (Velocity)	Spill Night TS (Velocity)
0			-40.36 (0.10)	-40.43 (0.12)
1	-34.14 (0.14)		-37.85 (0.13)	-35.77 (0.17)
2	-35.49 (0.12)	-39.78 (0.04)	-37.24 (0.23)	-37.43 (0.21)
3	-37.18 (0.21)	-39.02 (0.37)	-38.06 (0.29)	-39.05 (0.27)
4	-40.68 (0.22)	-40.48 (0.62)	-38.63 (0.32)	-38.47 (0.36)
5	-42.11 (0.25)	-40.34 (0.72)	-38.67 (0.33)	-39.32 (0.50)
6	-41.73 (0.27)	-41.86 (0.88)	-37.93 (0.43)	-38.97 (0.51)
7	-41.52 (0.37)	-41.61 (0.70)	-39.20 (0.57)	-39.55 (0.58)
8	-41.47 (0.31)	-42.50 (0.80)	-41.28 (0.52)	-39.56 (0.64)
9	-41.98 (0.40)	-41.97 (0.85)	-42.46 (0.67)	-40.31 (0.70)
10	-42.31 (0.40)	-40.25 (0.72)	-39.97 (0.68)	-40.10 (0.75)
11	-41.76 (0.41)	-42.06 (0.72)	-38.27 (0.91)	-38.44 (0.79)
12	-42.30 (0.47)	-40.43 (0.76)	-35.94 (0.78)	-37.65 (0.90)
13	-42.60 (0.35)	-40.52 (0.89)	-35.91 (1.01)	-37.61 (1.06)
14	-41.39 (0.38)	-40.48 (0.93)	-35.11 (1.03)	-38.79 (1.05)
15	-41.98 (0.44)	-37.61 (0.53)		
16		-39.26 (0.46)		
17		-38.89 (0.48)		

TS = target strength

2.3.2 Effective Beam Width

Effective beam width is the product of detectability modeling and used in generating the fish passage estimates. Mean velocity and target strength by range were combined with other deployment parameters such as ping rate, minimum number of echoes, beam width (measured at calibration), aiming angle, trajectory by range, and target strength threshold. Figure 6 illustrates the estimated effective beam widths for intake deployments. For most ranges, detectability was equal to or greater than the nominal beam width of 6°. No fish tracks were identified by the downlooking transducer at less than 2 m range; therefore, detectability in that range was assumed to be zero. Figure 7 illustrates the estimated effective beam widths for the spill deployments for day and night. The high ping rate (24 pps) helped maintain high estimated detectability except where the highest velocities occur, at ranges beyond 12 m.

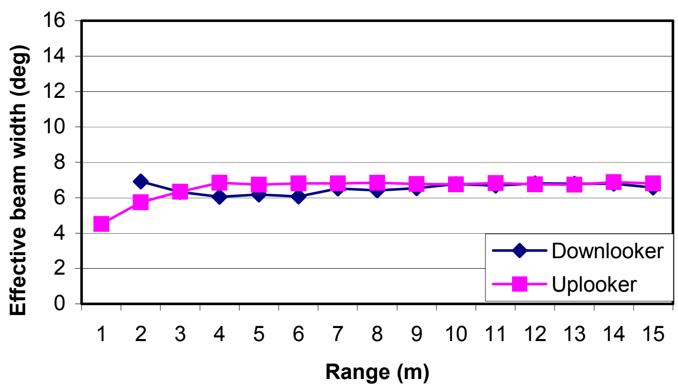


Figure 6. Estimated effective beam width for intake deployments.

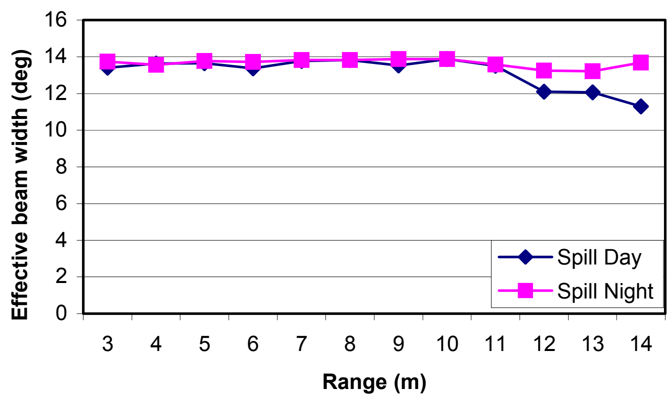


Figure 7. Estimated effective beam width for spillway deployments by day/night.

Detectability for single-beam transducers was estimated using velocity and target strength information obtained from the split-beam transducers. Fish velocities in three-dimensional space were converted to velocities perpendicular to the beam for each 1-m range from the transducer. The mean velocity and target strength were used to compute the effective beam width for each 1-m range. We used the combined detectability/Rayleigh method used by Ploskey et al. (2000) at The Dalles Dam in 1999 to compute effective beam width. No hydraulic flow data, on the order of the 1-m bins used for the analysis, were available for the deployments at John Day. This type of hydraulic data had the potential to aid in a missing value estimation of fish velocities. For this reason, current analysis relied more heavily on analysis of fish tracks through split-beams to estimate the velocities needed to compute detectability for single-beam transducers.

The detectability element of the method uses the effective beam angle output from a detectability model (D_ANGLE). The Rayleigh element uses a statistical model for backscattering cross-section to determine effective beam angle relative to the half power angle as a function of the backscattering and the system threshold. Scattering is expected to be Rayleigh distributed, as the ratio of fish length to wavelength would be about 35 for fish lengths of 125 mm and a 420 kHz acoustic system. Ehrenberg (circa 1985) showed the relationship between 1) the ratio of the effective angle to half power angle (RATIO), and 2) the difference in dB of mean back-scattering cross-section and system threshold. Finally, the Detectability/Rayleigh method incorporates detectability with the Rayleigh characteristics of the target strength distribution. Effective beam angle is the product of D_ANGLE and RATIO defined above.

2.4 Data Processing

2.4.1 Data Entry

Technicians viewing echograms on a computer screen selected fish tracks from single-beam data manually. Before data analysis, technicians were trained on track selection based on specific criteria. In-season estimates of both inter- and intra-tracker precision were made as part of the track identification quality assurance effort (see Appendix B for details). All split-beam data were processed with Vtrack™, an automated tracker, at BioSonics in Seattle, Washington. Due to the redundant single and split deployments for this study, the split-beam data were not used directly for fish passage estimation. This allowed us to relax the periods for tracking fish to those times when noise levels were relatively low. This procedure was important because split-beam phase angle data are more susceptible to acoustic noise than the range-only data of single-beams. Since fish velocities were derived from fish positions via the phase angle data, any error in the phase angle is propagated and amplified. The result is that the autotracker produced more reliable data. The data analysis process for split-beam data is described in greater detail in Appendix A.

2.4.2 Track Filtering

Additional track selection criteria were applied (Table 2) during subsequent processing, eliminating some of the manually selected tracks. Table 2 details the track selection criteria for all analyses. Some criteria were applied analytically after track identification because they are difficult to evaluate visually.

Table 2. Track selection criteria.

Track selection criteria	Used in manual track ID	Intake downlooker	Intake uplooker	Spill
Minimum number of echoes	Y	4	4	4
Maximum number of echoes	Y	200	200	200
Slope	N	-	-	Downward (away from transducer)
Direction of movement	N	-	Within 90º of downstream toward intake	Within 90º of downstream toward spillgate
Range	N	1m +	1m +	3m+
Linearity	Y	>.5	>.5	>.5
Avg. Narrow Pulse width	N	<0.47	<0.47	<0.47
Range Concentration	N	<0.08	<0.08	<0.08
Ping Concentration	N	>0.15	>0.15	>0.15

Track selection criteria applied to the raw data were used to analytically eliminate a portion of tracks selected visually (manually tracked). If a technician selected a track that did not meet one or more of the selection criteria, the track was eliminated during processing. At the spill bays, the greatest number of fish tracks eliminated were due to a failure to meet the slope criteria (Table 3). The eliminated tracks did not indicate the fish were moving downward toward the tainter gate opening and, therefore, committed to passing. At the intakes, the greatest numbers of fish eliminated were due to a failure to meet the narrow pulse width criteria, indicating that some tracks contained echoes inconsistent with juvenile salmonid smolts.

The proportion of fish moving toward the dam in split-beam deployments (Table 23 (spill) and figures 59 and 60 (Intake uplooker), appendix A:1) was used to estimate the number of tracks that were committed to passing. Individual tracks were not eliminated, because the directional information is not available for single beam transducers. Instead, the number of tracks was multiplied by the proportion moving toward the dam to reduce the total number of tracks to an estimated number or committed tracks.

Table 3. Percent of fish tracks eliminated by track selection criteria.

Track selection criteria	Percent eliminated (Spill)	Percent eliminated (intake)
Minimum number of echoes	<1	<1
Maximum number of echoes	<1	<1
Slope	25	N/A
Direction of movement	33	28
Range	9	N/A
Linearity	5	<1
Avg. Narrow Pulse width	4	9
Range Concentration	<1	<1
Ping Concentration	<1	<1

2.5 Data Analysis

2.5.1 Passage Metrics

The fish passage metrics used in this study are defined below. Spill efficiency (SPY) describes the proportion of fish that passed through the spillway (Equation 1). Spill effectiveness (SPS) describes SPY in terms of the proportion of water that passed through the spillway (Equation 2). Fish guidance efficiency (FGE) is the proportion of fish guided into the gatewell over all the fish that enter the intake (Equation 3). Fish passage efficiency (FPE) is the project-wide metric describing the proportion of non-turbine passed fish that pass the dam (Equation 4). These definitions are consistent with those reported in other studies in the region (Skalski, 2000).

$$SPY \equiv \frac{\mathrm{X}_{spill}}{\mathrm{X}_{spill} + \mathrm{X}_{guided} + \mathrm{X}_{unguided}} \tag{1}$$

$$SPS \equiv \frac{SPY}{Q_{spill} \Big/ \left(Q_{spill} + Q_{powerhouse}\right)} \tag{2}$$

$$FGE \equiv \frac{\mathrm{X}_{guided}}{\mathrm{X}_{guided} + \mathrm{X}_{unguided}} \tag{3}$$

$$FPE \equiv \frac{\mathrm{X}_{spill} + \mathrm{X}_{guided}}{\mathrm{X}_{spill} + \mathrm{X}_{guided} + \mathrm{X}_{unguided}} \tag{4}$$

2.5.2 Statistical Methods

This analysis assumed that the questions of interest pertain to the effects of the spill treatments on passage through the project as a whole. The operational question of interest was whether spill treatment affected fish passage routes, timing, or magnitude. Potentially, fish that do not pass during the daytime portion of the "0 spill" treatment will pass during the nighttime. That is, they will choose to hold in the spillway forebay during the day rather than passing through the powerhouse. Therefore, treatment comparisons were analyzed by 24-h periods comprised of a daytime treatment and the following nighttime period.

Spill treatment effects were tested using a randomized complete block design. Spill treatment and block effects were included as factors in an ANOVA analysis of fish guidance efficiency, fish passage efficiency, spill efficiency and spill effectiveness. Spill was treated as a fixed effect; blocks were treated as having random effects. All interactions between the two factors were included in the ANOVA. An appropriate error term was constructed for each effect.

A more comprehensive ANOVA was conducted for each passage metric to more closely examine the effect of day/night passage times. In these anovas, day-night was added as a random factor, along with all possible interactions. Because treatments are evaluated on a 24hr basis, and because spill treatments are always 60% at night, the effect of day/night differences are confounded with the treatments, and that confounding must be considered in the interpretation of this ANOVA. The current experimental design is inadequate to fully evaluate the effects of day/night independent of the treatment factors.

3.0 Results

3.1 River Discharge and Dam Operations

Hourly dam operations data were obtained from the powerhouse operator every hour on the half-hour by telephone, 24 hours/day, 7 days/week. Daily data on mean forebay level, total outflow, and spill proportion were calculated from information available on the Data Access in Real Time (DART) web site (http://www.cqs.washington.edu/dart). Total project discharge ranged from 150 to 241 kcfs during the study period, and mean project discharge was 194 kcfs during the study period (Figure 8). Hourly discharge rates from both the spillway and powerhouse are shown in Figure 9 from data collected during this study. Spill levels changed at 0600 h and 1900 h. Figure 10 shows the hourly spill and treatment block for each day sampled in 2000. Spill operations closely followed the treatment schedule. Block 1 was incomplete and was excluded from further analysis.

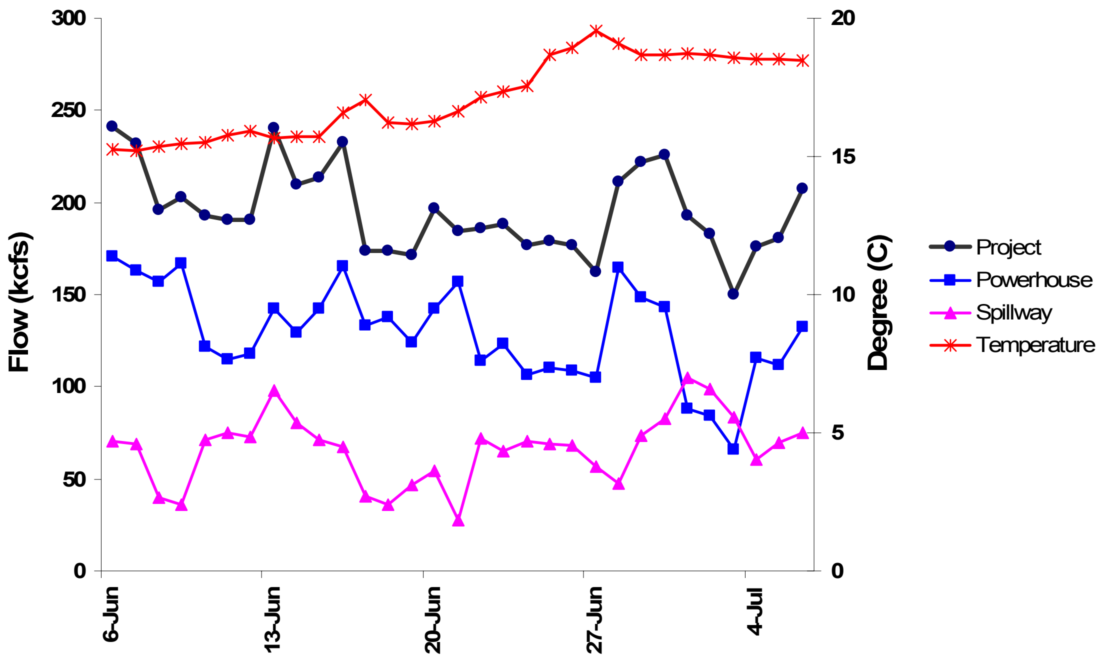


Figure 8. Daily average dam operations for the study period.

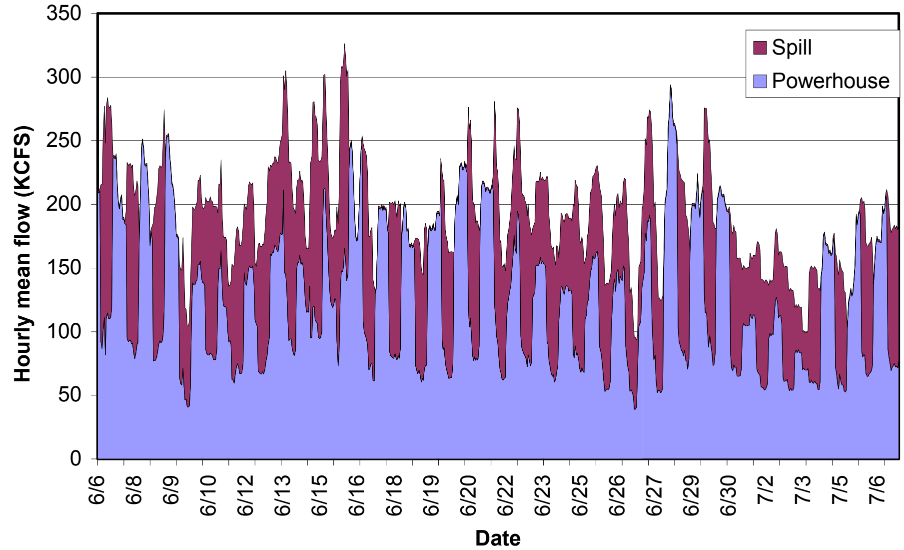


Figure 9. Hourly mean total flows with relative spill and powerhouse flows illustrated.

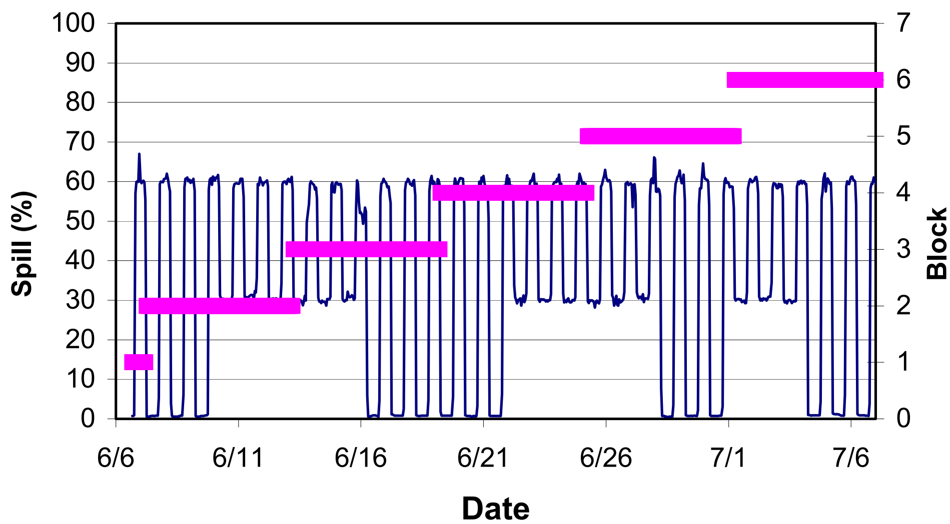


Figure 10. Hourly dam operations showing the implemented spill regime.

Figure 11 illustrates the percent spill by hour for each block and treatment level. Percent spill for a given treatment did not differ greatly among blocks. Therefore, any difference in fish passage between blocks was not likely due to dam operations. The daytime spill pattern concentrated spill flows to the north, away from the powerhouse (Figure 12). It is important to note that the 0% treatment rarely achieved 0% spill, because Bay 1 was operated almost continuously to provide attraction water for the adult fishway (Figure 12). Bay 1 discharge during the 0% spill condition was 1.7 kfcs. Spill flows were slightly higher at night following 0% daytime spill (Figure 13), but the spillway discharge following either 0% or 30% daytime spill were similar. Daytime turbine flows were similar during both spill treatments (Figure 14). During nighttime, the flows at Units 2, 10, and 14 differed among spill treatments (Figure 15).

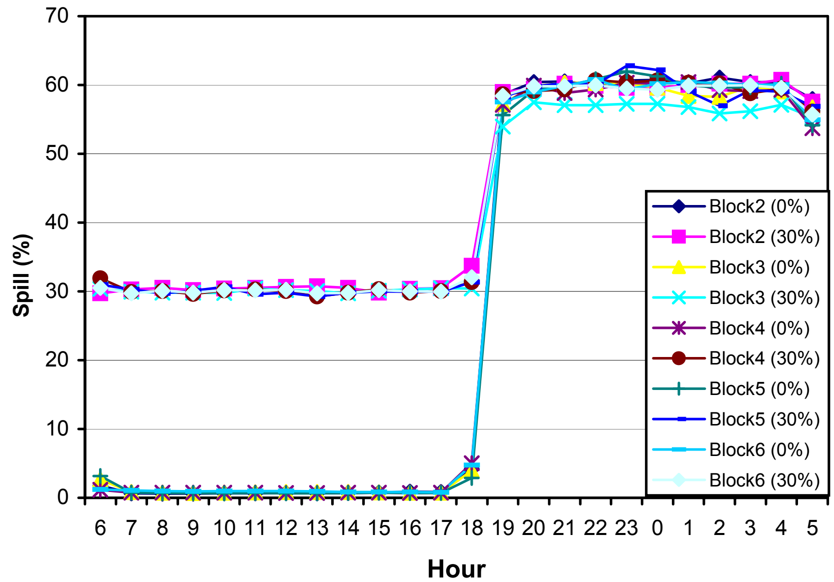


Figure 11. Mean hourly spill percent by treatment and block.

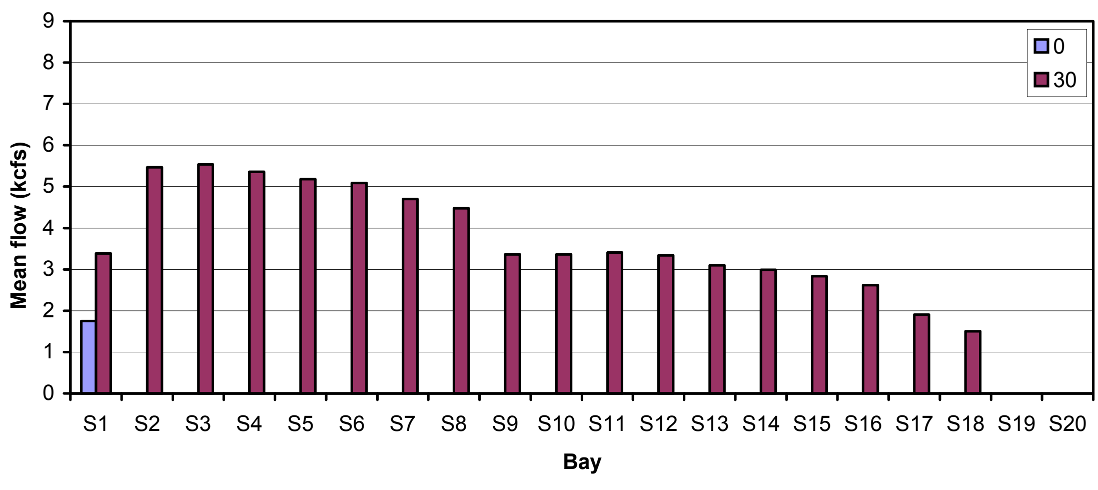


Figure 12. Mean daytime spill flow by spill bay and treatment.

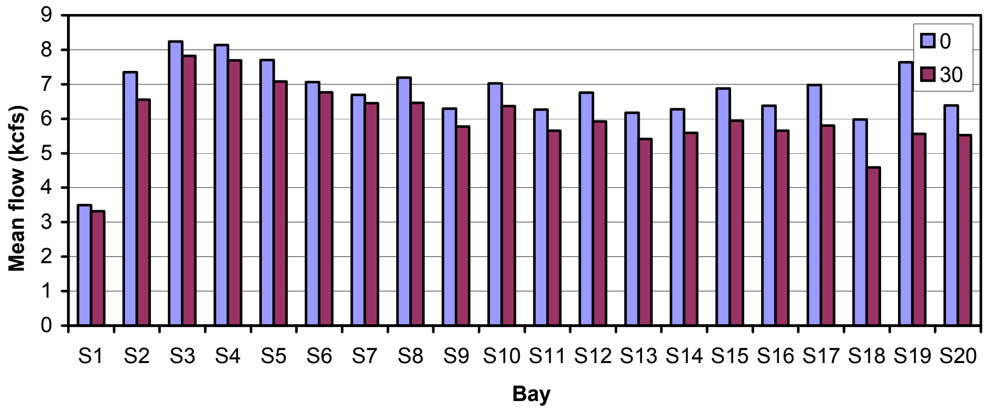


Figure 13. Mean nighttime spill flow by spill bay and treatment.

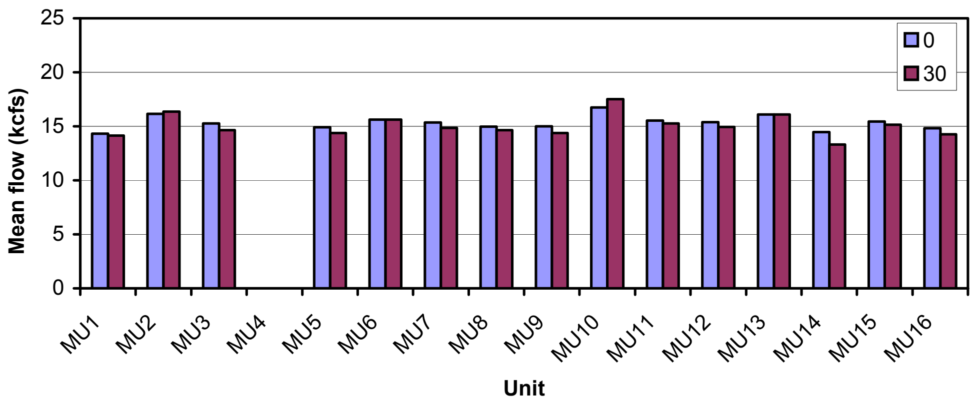


Figure 14. Mean daytime flow by turbine unit and treatment.

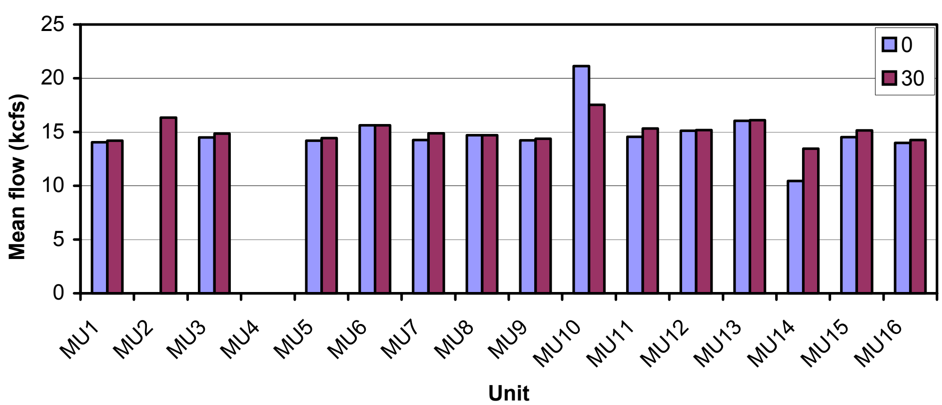


Figure 15. Mean nighttime flow by turbine unit and treatment.

3.2 Species Composition and Run Timing

Species composition data were obtained from the Smolt Monitoring Program via the Data Access in Real Time web site (http://www.cqs.washington.edu/dart). Passage was predominantly (92%) subyearling chinook salmon (*Oncorhyncus tshawytsc*ha) during all treatment blocks. Thus, partitioning of the data set was not necessary and all data analyses assumed species composition to consist of one season: summer.

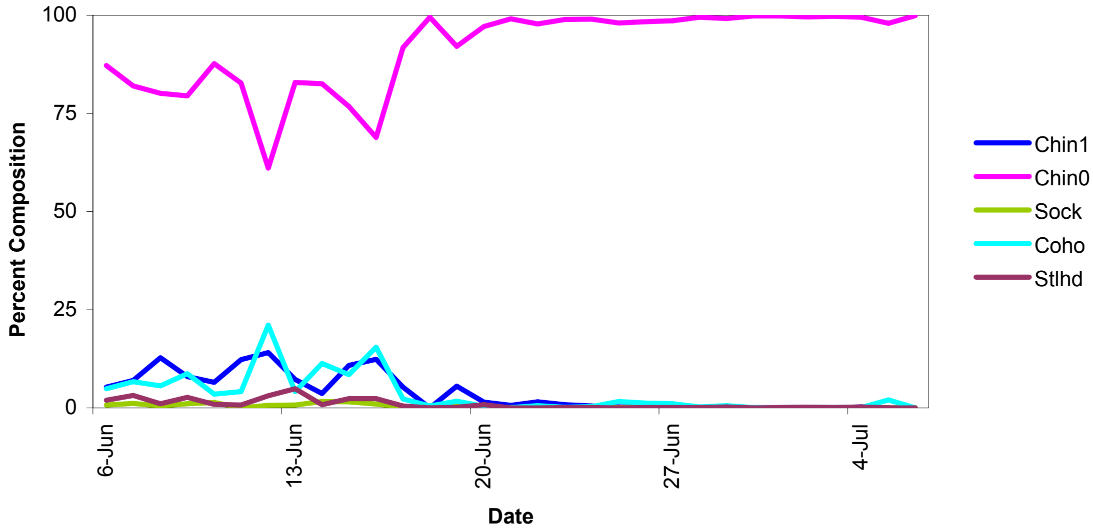


Figure 16. Species composition from the 2000 Smolt Monitoring Program at John Day Dam.

Powerhouse run timing of fish detected by hydroacoustic methods was consistent with the magnitude and trends through time estimated in the John Day Dam Smolt Monitoring Program (Figure 17). This comparison was based upon powerhouse detections and expansions consistent with those used in the Smolt Monitoring Program. Estimated spillway and powerhouse passage were compared over time, as shown in Figure 18. Spillway passage was generally greater than 80% of total passage for any 24-h period, regardless of what spill treatment was imposed during daytime. Figure 19 shows that spill treatments had a large effect on the rate of spill passage, but powerhouse passage rates remained consistently low.

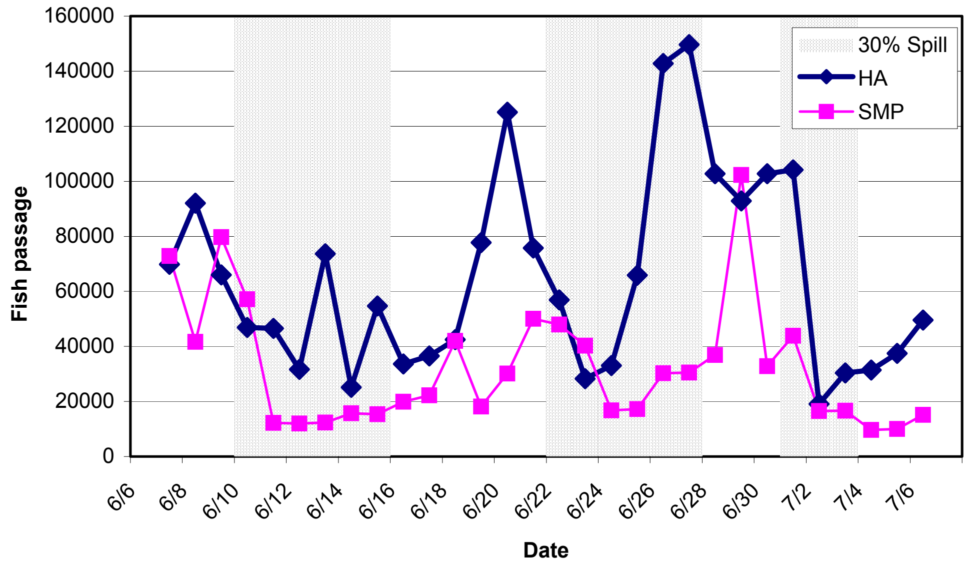


Figure 17. Powerhouse run timing of fixed-location hydroacoustic methods and the Smolt Monitoring Program at John Day Dam.

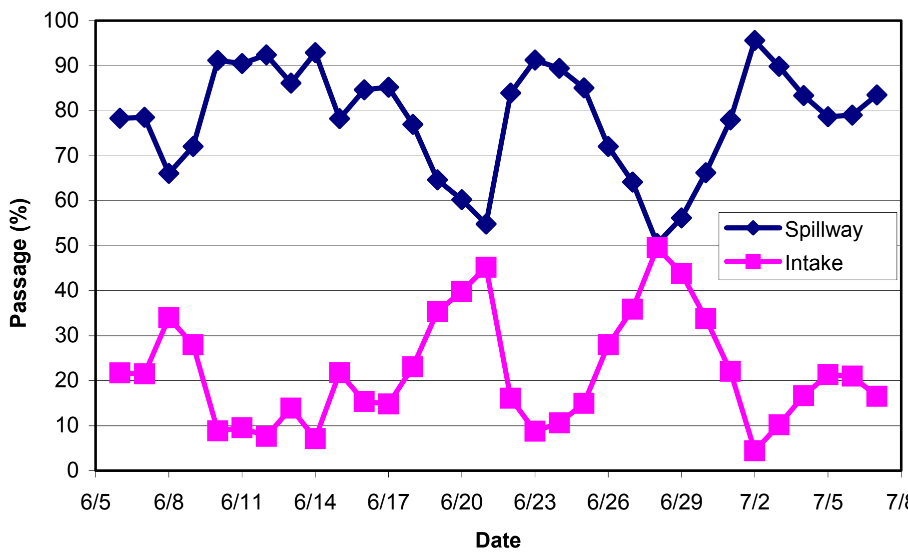


Figure 18. Relative contributions of the powerhouse and spillway passage.

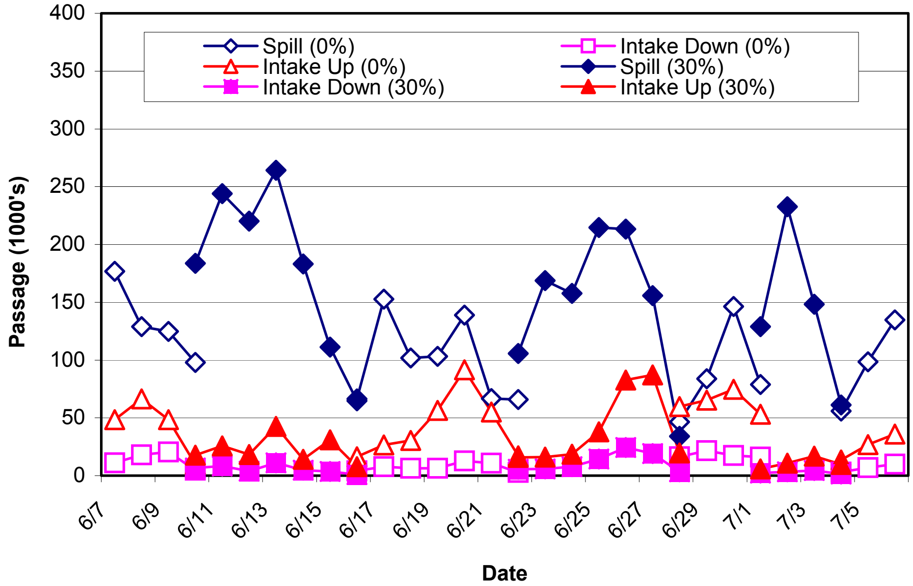


Figure 19. Run timing by deployment type.

3.3 Efficiency and Effectiveness

Our analysis shows that the majority of fish used the spillway for passage at John Day Dam in 2000. Daily estimates are plotted to examine temporal trends over the season. Then, fish passage efficiency and effectiveness metrics are shown by treatment for the study as a whole. The metrics are examined for treatment and block effects, and also the treatment, block, day/night, and interaction effects. Daily passage metrics are plotted in relation to spill discharge to illustrate possible trends. Finally, the results from this study are compared to previous hydroacoustic studies.

3.3.1 Daily Fish Passage Metrics

No persistent temporal biases are apparent in the fish passage metrics (Figure 20). Treatment changes are highlighted and also readily apparent from spill effectiveness estimates.

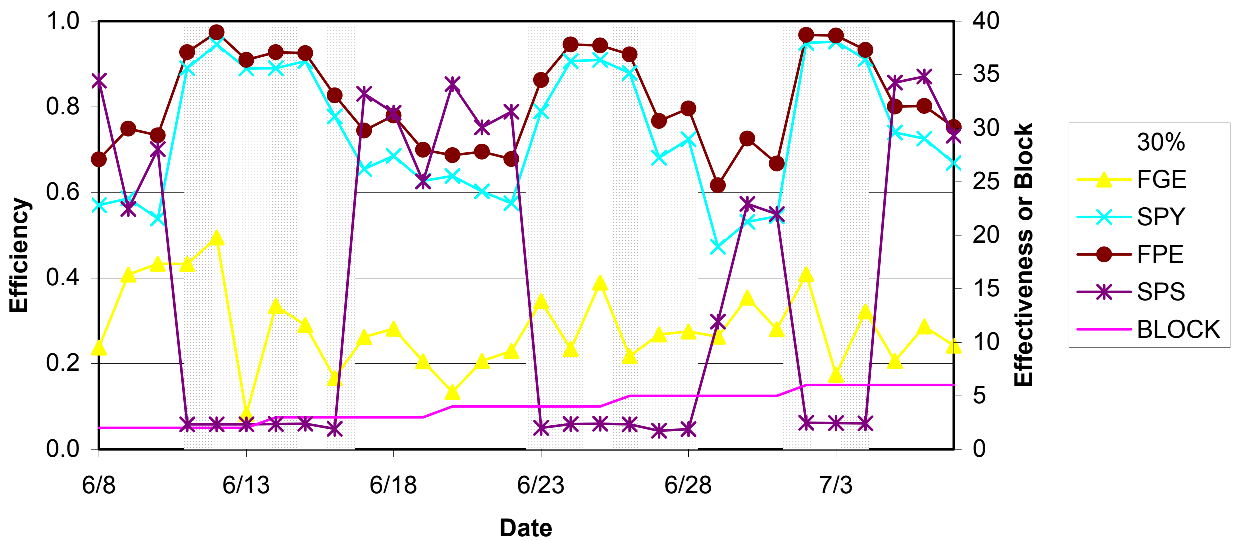
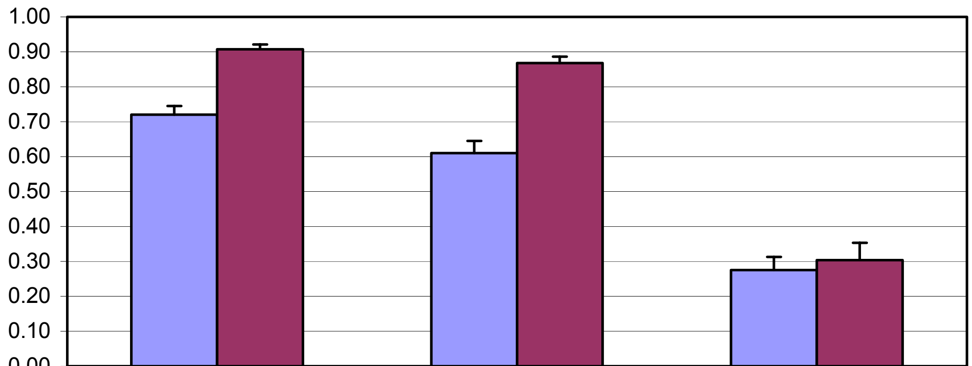


Figure 20. Daily estimates of fish passage efficiency, spill efficiency, fish guidance efficiency, and spill effectiveness

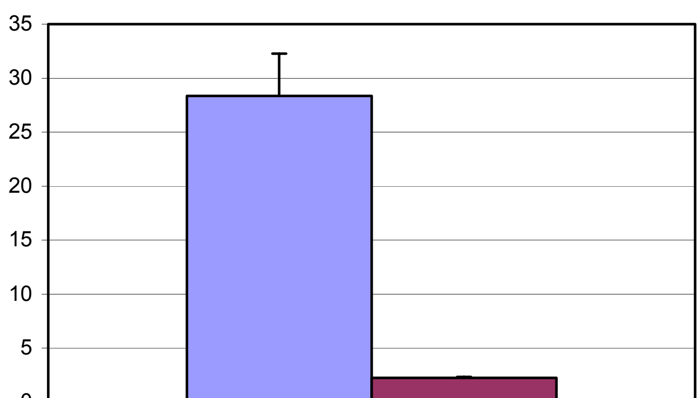
3.3.2 Fish Passage Metrics by Treatment

All fish passage efficiency metrics were lower during the 0% daytime spill treatment than during the 30% daytime spill treatment (Figure 21). These are 24-hr estimates. Spill during the nominal 0% treatment was never completely shut off because spillbay 1 remained on to provide adult attraction flows. Fish passage efficiency was driven primarily by the differences in spill efficiency, but FGE was also lower during 0% the daytime spill treatment. Spill effectiveness showed the opposite trend. While more fish passed via non-turbine routes during the 30% daytime spill treatment, spill effectiveness was much lower during that period (Figure 22).



	FPE	SPY	FGE
0	0.72	0.61	0.28
30	0.91	0.87	0.30

Figure 21. Efficiency metric summary chart and table. FPE = fish passage efficiency; SPY = spill efficiency; FGE = fish guidance efficiency. Error bars are 95% confidence intervals.



	SPS
0	28.36
30	2.25

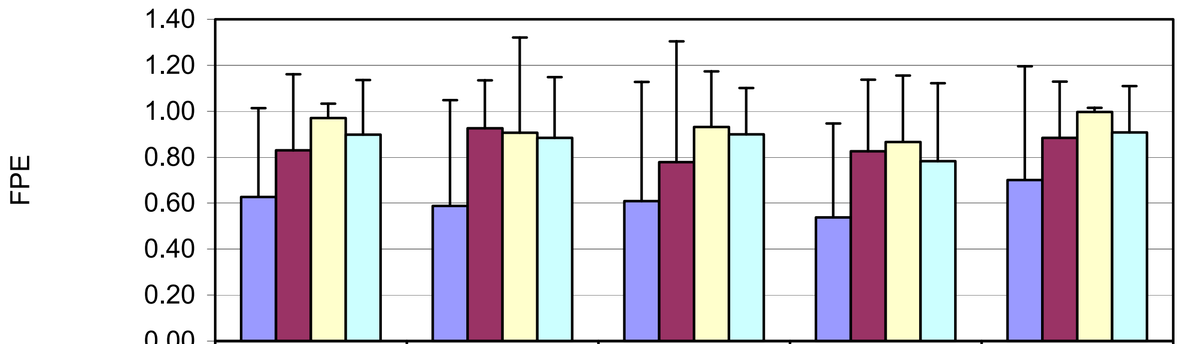
Figure 22. Spill effectiveness summary chart and table. Error bars are 95% confidence intervals.

3.3.3 Treatment and Block Effects

Analysis of variance tables were generated for examination of treatment and block effects for all the efficiency and effectiveness fish passage metrics. Treatment effects were significant for fish passage efficiency, spill efficiency, and spill effectiveness, but not for FGE (Tables 4-7 and Figures 23-26). No other effects were significant at the 5% level. Further, FPE always increased during the night of a 0% daytime spill treatment, and always decreased during the night of a 30% daytime spill treatment (Table 4 and Figure 23). FGE estimates were highly variable with neither treatment nor block effects being significant (Table 6 and Figure 25). Spill effectiveness values were extremely high and spill efficiencies were low during the daytime of a 0% daytime spill treatment (when only spill bay 1 was open to maintain attraction flows to the adult fishways). Also, 30% daytime spill was more effective at passing fish than the 60% nighttime spill of either treatment (Table 7 and Figure 26).

Table 4. ANOVA results for Fish Passage Efficiency for block and treatment effects.

	Effect type	df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	5.269166	4.0982	0.066373	79.38693	0.000784*
BLOCK	Random	4	0.207007	4.0000	0.067020	3.08873	0.150191
TRTGRP *BLOCK	Random	4	0.067020	499.0000	0.037060	1.80843	0.125879

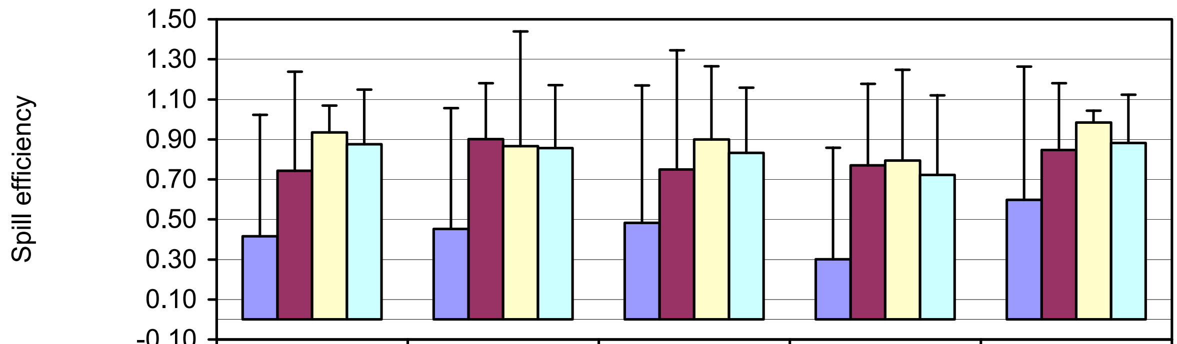


	2	3	4	5	6
Day 0%	0.63	0.59	0.61	0.54	0.70
Night 0%	0.83	0.93	0.78	0.83	0.88
Day 30%	0.97	0.91	0.93	0.87	1.00
Night 30%	0.90	0.88	0.90	0.78	0.91

Figure 23. FPE by treatment, day/night, and block.

Table 5. ANOVA results for spill efficiency for block and treatment effects.

	Effect type	Df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	9.597970	4.1995	0.064280	149.3159	0.000194*
BLOCK	Random	4	0.391508	4.0000	0.064118	6.1060	0.053837
TRTGRP *BLOCK	Random	4	0.064118	499.0000	0.071594	0.8956	0.466314



	2	3	4	5	6
Day 0%	0.42	0.45	0.48	0.30	0.60
Night 0%	0.74	0.90	0.75	0.77	0.85
Day 30%	0.94	0.87	0.90	0.79	0.98
Night 30%	0.88	0.86	0.83	0.72	0.88

Figure 24. Spill efficiency by treatment and block and day/night.

Table 6. ANOVA results for Fish Guidance Efficiency for block and treatment effects.

	Effect type	df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	0.186173	4.2031	0.104098	1.788439	0.248904
BLOCK	Random	4	0.251311	4.0000	0.103792	2.421299	0.206353
TRTGRP *BLOCK	Random	4	0.103792	499.0000	0.117979	0.879750	0.475803

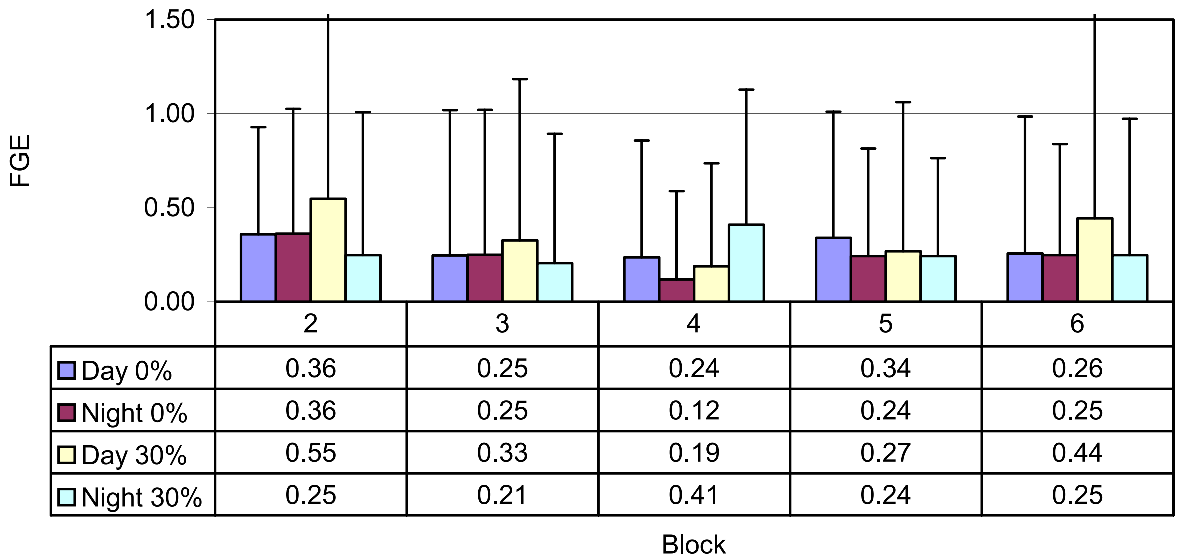
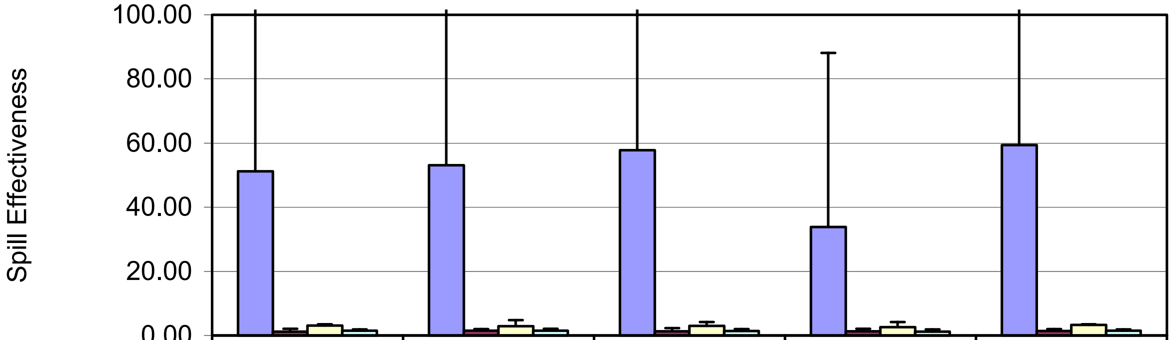


Figure 25. FGE by treatment, day/night, and block.

Table 7. ANOVA results for spill effectiveness for block and treatment effects.

	Effect type	df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	76398.70	4.2241	582.1076	131.2450	0.000244*
BLOCK	Random	4	627.37	4.0000	578.9490	1.0836	0.469915
TRTGRP *BLOCK	Random	4	578.95	499.0000	725.2639	0.7983	0.526671



	2	3	4	5	6
Day 0%	51.22	53.14	57.82	33.87	59.34
Night 0%	1.24	1.53	1.28	1.31	1.43
Day 30%	3.06	2.89	2.98	2.64	3.26
Night 30%	1.47	1.52	1.40	1.22	1.49

Figure 26. Spill effectiveness by treatment, day/night, and block.

3.3.4 Treatment, Block, and Day/Night Effects

Treatment, block, day/night, and interaction effects for the various passage metrics are shown in Table 8 through Table 11. With the exception of FGE, the TRTGROUP*DAYNIGHT interaction was the only significant effect. The significance of this effect can be interpreted to mean that the day to night differences in fish passage were significantly different among treatment groups. This is to be expected because of the way the 0% and 30% spill treatments were imposed during the day with 60% spill at night in both treatments. The lack of significance for this effect in FGE may result from the difficulty in estimating this metric with current deployments, which has the effect of inflating the error sums of squares. Also, in many hours that were estimable, low numbers of fish resulted in FGE with a value of 0 or 1. These problems limited the ability to compute an ANOVA with all interactions included, so the higher order interaction was dropped to allow computation of the other effects.

Table 8. Treatment, block, and day/night analysis of variance for FPE.

	Effect type	df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	4.441954	1.0231	2.355608	1.88569	0.396929
DAYNIGHT	Random	1	0.905942	1.0015	2.330418	0.38875	0.644949
BLOCK	Random	4	0.208078	2.2355	0.082903	2.50989	0.285264
TRTGRP*DAYNIGHT	Random	1	2.328396	4.1563	0.051847	44.90866	0.002247
TRTGRP*BLOCK	Random	4	0.080810	4.0000	0.052645	1.53500	0.344066
DAYNIGHT*BLOCK	Random	4	0.054738	4.0000	0.052645	1.03976	0.485383
TRTGRP*DAYNIGHT *BLOCK	Random	4	0.052645	489.0000	0.029074	1.81075	0.125465

Table 9. Treatment, block, and day/night analysis of variance for spill efficiency.

	Effect type	df effect	MS effect	df error	MS error	F	p
TRTGRP	Fixed	1	7.885397	1.0128	4.559436	1.72947	0.411830
DAYNIGHT	Random	1	2.584244	1.0153	4.564965	0.56610	0.587820
BLOCK	Random	4	0.378347	3.1259	0.122659	3.08455	0.184658
TRTGRP*DAYNIGHT	Random	1	4.530232	4.2725	0.056398	80.32601	0.000629
TRTGRP*BLOCK	Random	4	0.086709	4.0000	0.056481	1.53519	0.344025
DAYNIGHT*BLOCK	Random	4	0.092431	4.0000	0.056481	1.63649	0.322455
TRTGRP*DAYNIGHT *BLOCK	Random	4	0.056481	489.0000	0.054028	1.04540	0.383184

Table 10. Treatment, block, and day/night analysis of variance for FGE.

	Effect type	df effect	MS effect	df error	MS error	F	P
TRTGRP	Fixed	1	1	0.253168	0.1373	0.023276	10.8766
DAYNIGHT	Random	1	1	0.426642	0.0003	0.000957	445.6154
BLOCK	Random	4	4	0.244959	0.7427	0.053310	4.5950
TRTGRP*DAYNIGHT	Random	1	1	0.041188	493.0000	0.117854	0.3495
TRTGRP*BLOCK	Random	4	4	0.097966	493.0000	0.117854	0.8312
DAYNIGHT*BLOCK	Random	4	4	0.073425	493.0000	0.117854	0.6230

Table 11. Treatment, block, and day/night analysis of variance for spill effectiveness.

	Effect type	df effect	MS effect	df error	MS error	F	p
TRTGRP	Fixed	1	55593.45	0.9990	56199.46	0.9892	0.501857
DAYNIGHT	Random	1	63946.74	1.0007	56246.47	1.1369	0.479499
BLOCK	Random	4	448.09	1.2961	401.78	1.1153	0.571560
TRTGRP*DAYNIGHT	Random	1	56226.77	4.3080	410.74	136.8900	0.000199
TRTGRP*BLOCK	Random	4	381.39	4.0000	409.65	0.9310	0.526785
DAYNIGHT*BLOCK	Random	4	430.04	4.0000	409.65	1.0498	0.481792
TRTGRP*DAYNIGHT *BLOCK	Random	4	409.65	489.0000	441.87	0.9271	0.447842

3.3.5 In Relation to Spill Discharge

The following graphs show passage metrics by absolute spill discharge by spill treatment. The plotted values are shown with a loess curve fit, which is preferred when no assumptions are made as to the nature of the relationship. Treatment differences are obvious and in the expected direction, with the exception of FGE (Figure 27 through Figure 30). Greater spill leads to greater FPE and SPY, but lower SPS. Within treatments, the trends with spill discharge are not clear. In the 0% spill treatment, there is a weak trend with increasing spill discharge toward lower FPE and possibly SPY. These plots do not account for changes in turbine outflows during the day during 0% treatment days.

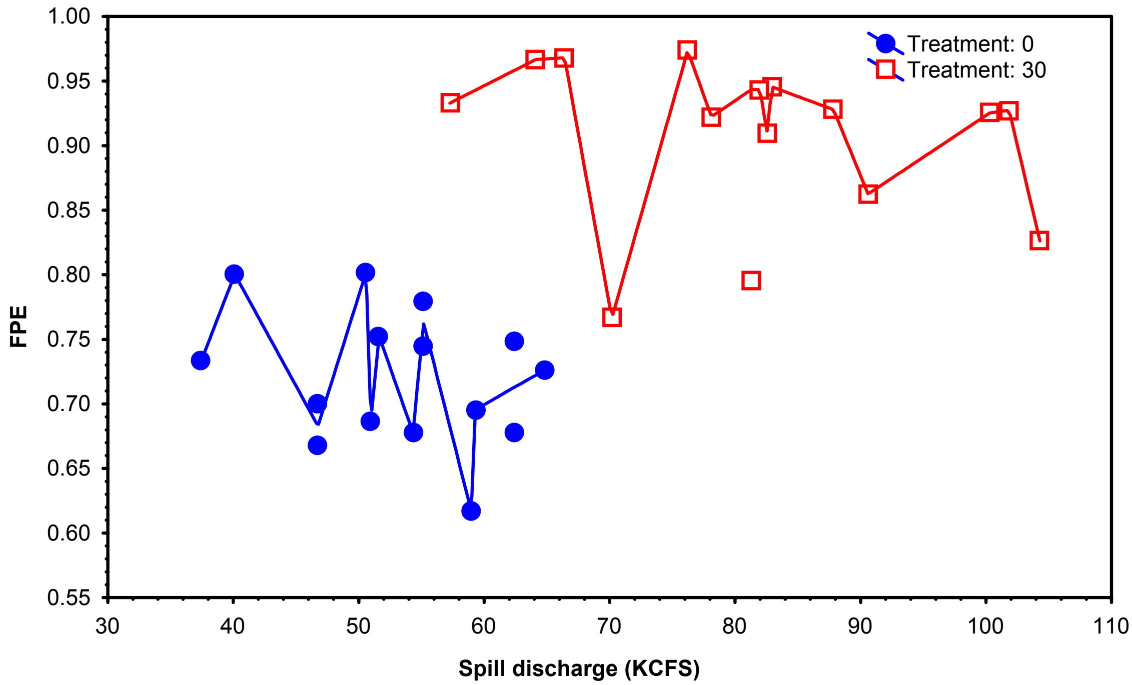


Figure 27. FPE per spillway discharge by treatment with lowess curve fit.

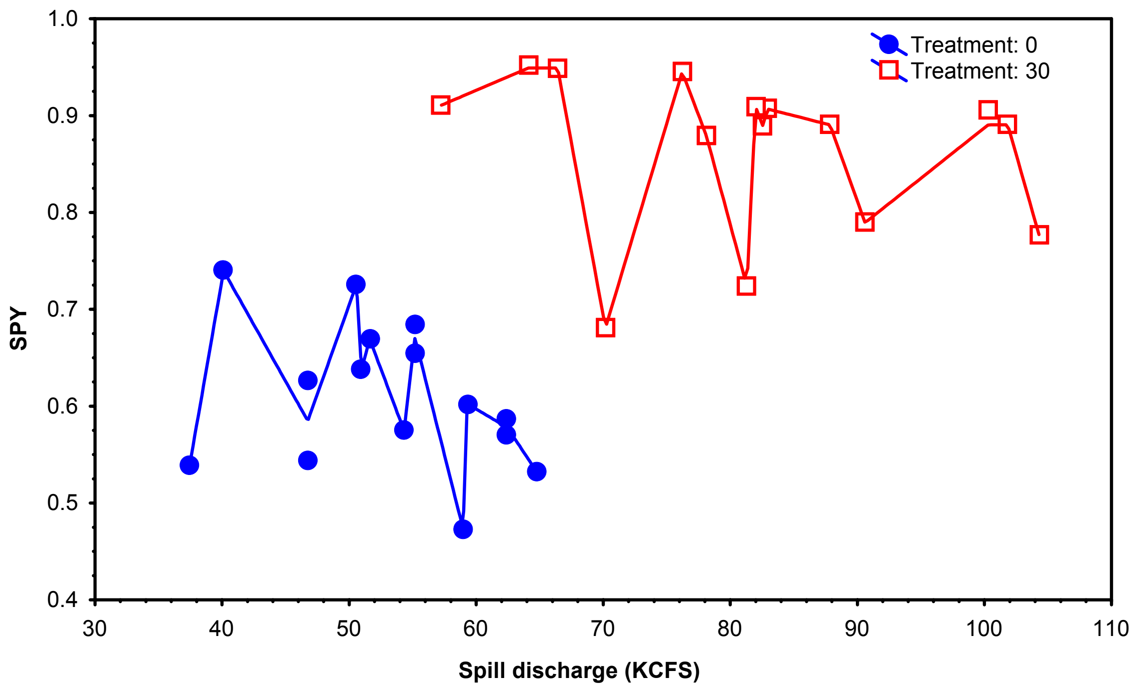


Figure 28. Spill efficiency per spillway discharge by treatment with lowess curve fit.

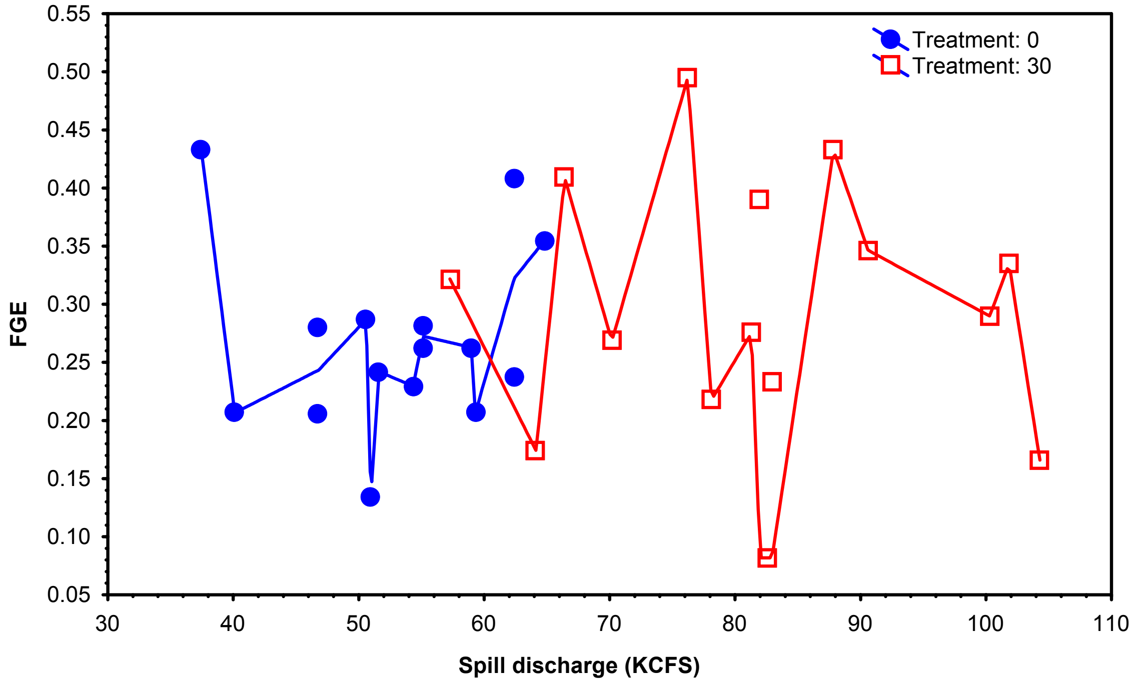


Figure 29. FGE per spillway discharge by treatment with lowess curve fit.

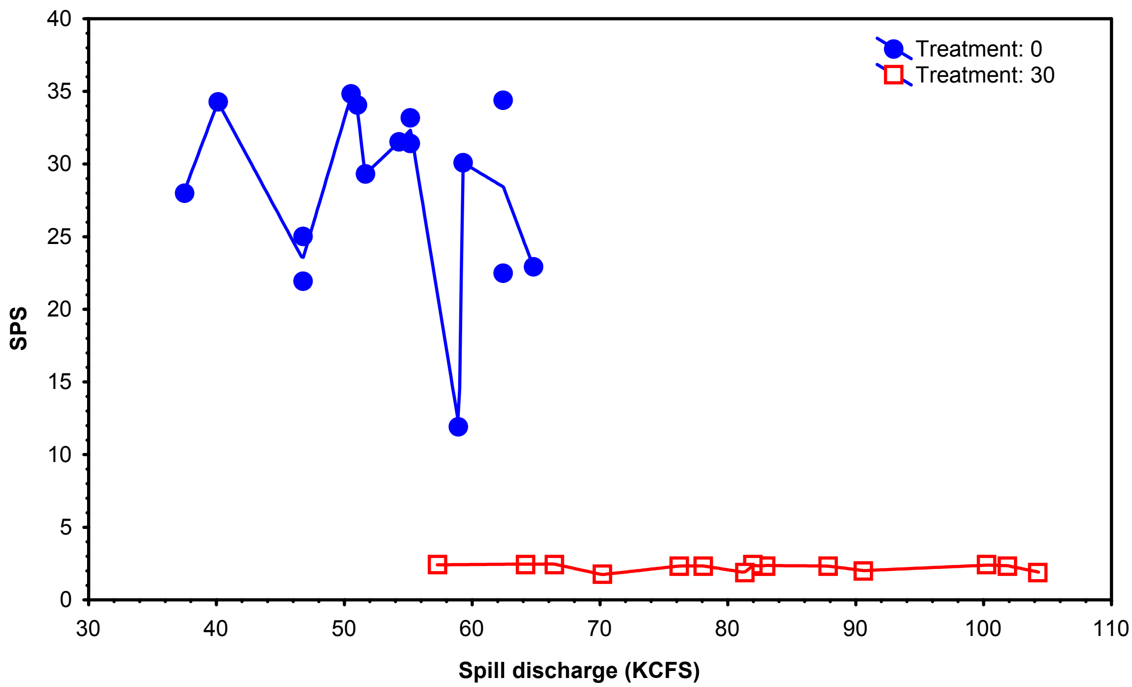


Figure 30. Spill effectiveness per spillway discharge by treatment with lowess curve fit.

3.3.6 Inter-annual Hydroacoustic Data Comparison

Results from recent hydroacoustics studies are shown for comparison in Table 12. The results from this study comport with the results from the 1999 study (Johnston et al. 2000). Previous year studies in 1989 (McFadden and Hedgepeth 1990), 1988 (Ouellette 1988), 1987 (Johnson and Wright 1987), and 1986 (Kuehl 1987) all reported lower spill efficiencies. The 1989 to 1986 studies had considerably less spill than did 1999 and 2000, as shown in Figure 31. When spill did occur in the 1986 – 1989 studies, it was at the south side of the spillway beginning with Bay 20. A concurrent study synthesized juvenile salmonid passage data from both hydroacoustic and radio tag methods for John Day Dam (Poe, Anglea, and Giorgi, 2001) in greater detail. The reader is referred to that document for an in-depth discussion of juvenile fish passage, which is beyond the scope of this report.

Table 12. Comparison of 2000 results with previous hydroacoustic studies.

Year-Season	2000 summer	1999 spring	1999 summer	1989 summer	1988 summer	1987 summer	1986 summer
Period	6/6-7/7	5/1-5/30	6/6-7/8	6/11-8/23	6/9-8/15	6/7-8/15	7/13-8/15
#days	32	16	10	44	68	39	34
Spill %Q	35%	29%	24%	21%	no data	no data	31%
Spill Efficiency	74[1]	75%[1]	78%[1]	28%	19%	18%	32%
Spill Effectiveness	2.25	2.74	3.76	1.4	1.1	1.3	1.03

[1]Average of both 0% and 30% spill treatments

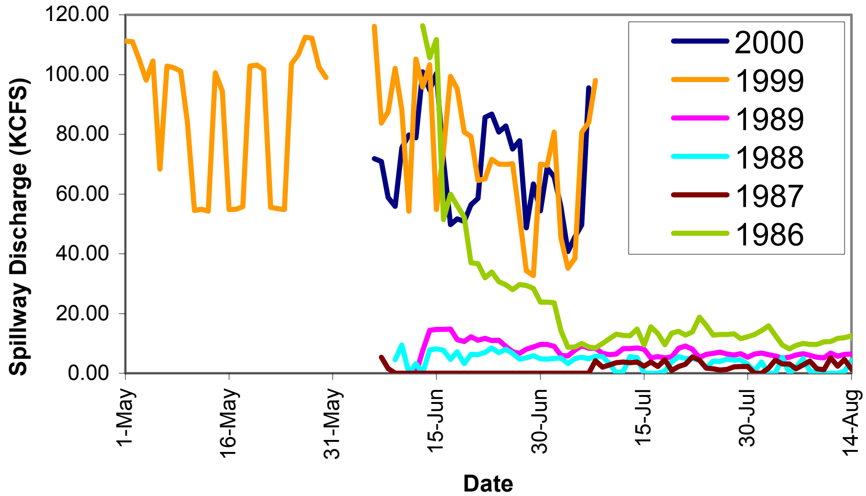


Figure 31. Comparison of historical spillway discharge for the time periods of previous hydroacoustic studies at John Day Dam. Based on data from DART.

3.4 Vertical Distributions

The uplooking transducers detected few fish close to the intake ceiling (Figure 32 and Figure 33). The downlooking transducers detected few fish near the intake floor (Figure 34 and Figure 35). The intake uplooking and downlooking deployments have overlapping vertical ranges but sample a different horizontal volume for a given elevation (see Figure 4). If the fish were following a flat trajectory, we would expect uplooking and downlooking vertical distributions to match. Vertical distribution at the spillway was more concentrated near the surface during daytime than at night, regardless of the spill treatment (Figure 36 and Figure 37).

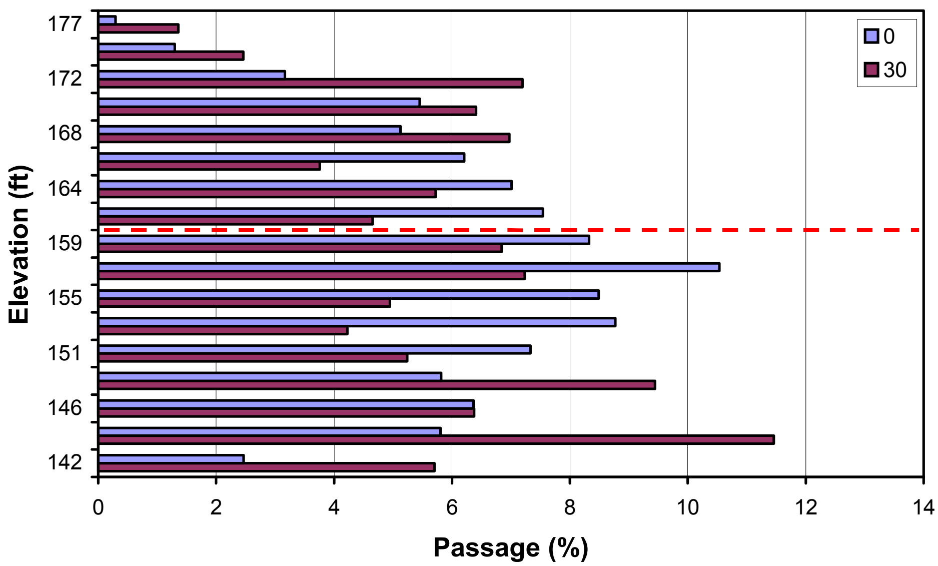


Figure 32. Vertical distribution of fish passage expressed as a percent of passage at the powerhouse uplooking transducer during daytime by treatment. The dotted line is the approximate elevation of the screen tip.

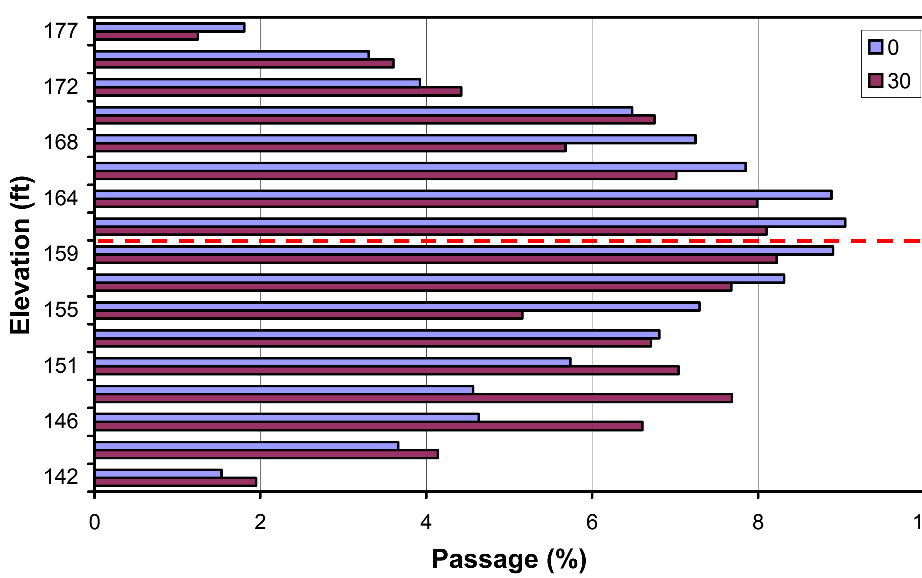


Figure 33. Vertical distribution of fish passage expressed as a percent of passage at the powerhouse uplooking transducer during nighttime by treatment. The dotted line is the approximate elevation of the screen tip.

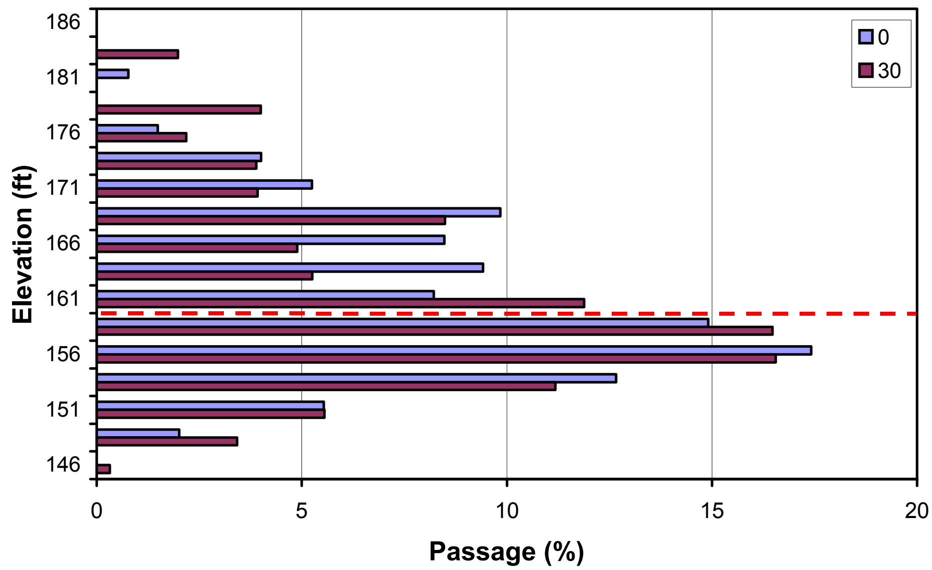


Figure 34. Vertical distribution of fish passage expressed as a percent of passage at the powerhouse downlooking FGE transducer during daytime by treatment. The dotted line is the approximate elevation of the screen tip.

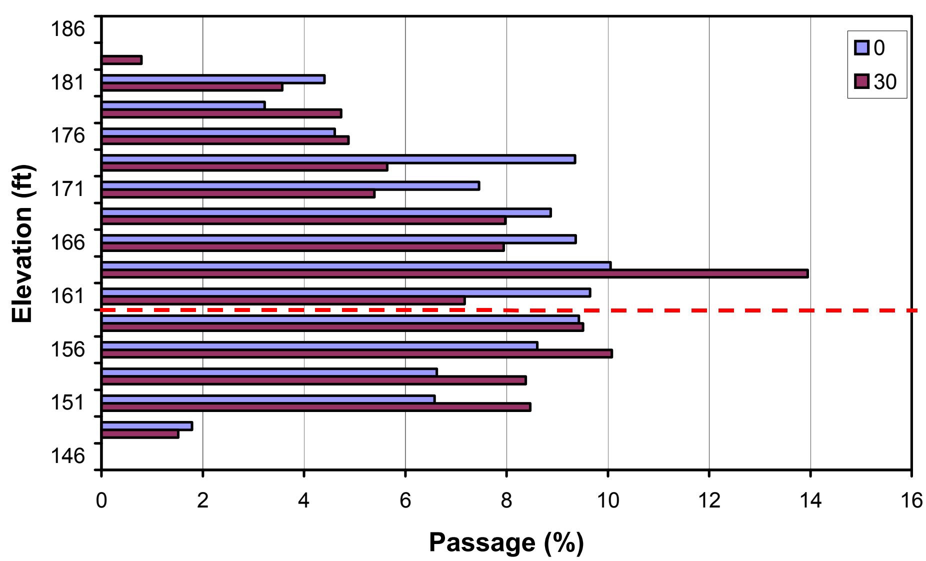


Figure 35. Vertical distribution of fish passage expressed as a percent of passage at the powerhouse downlooking FGE transducer during nighttime by treatment. The dotted line is the approximate elevation of the screen tip.

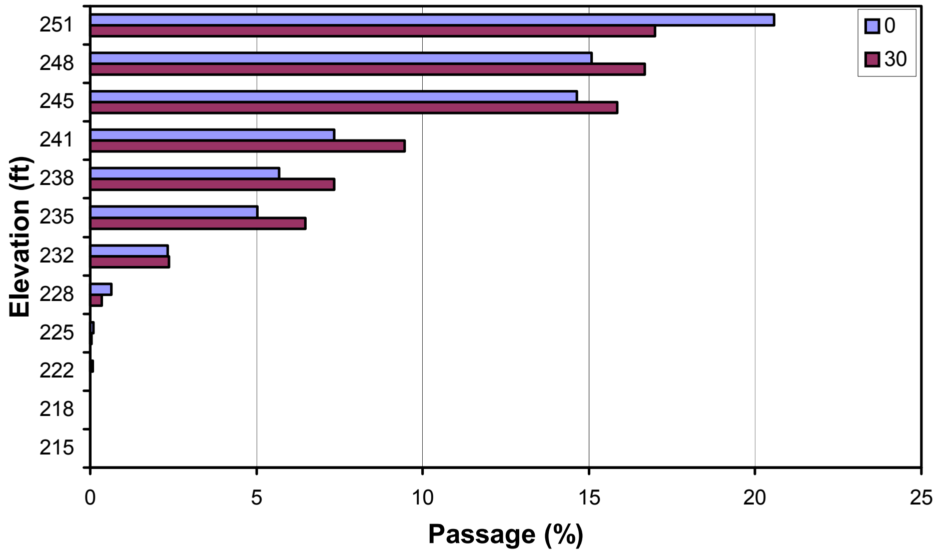


Figure 36. Vertical distribution of passage at the spillway during daytime by treatment. The crest of the spillway ogee was Elevation 210 ft, and the normal forebay pool elevation was at Elevation 254 ft.

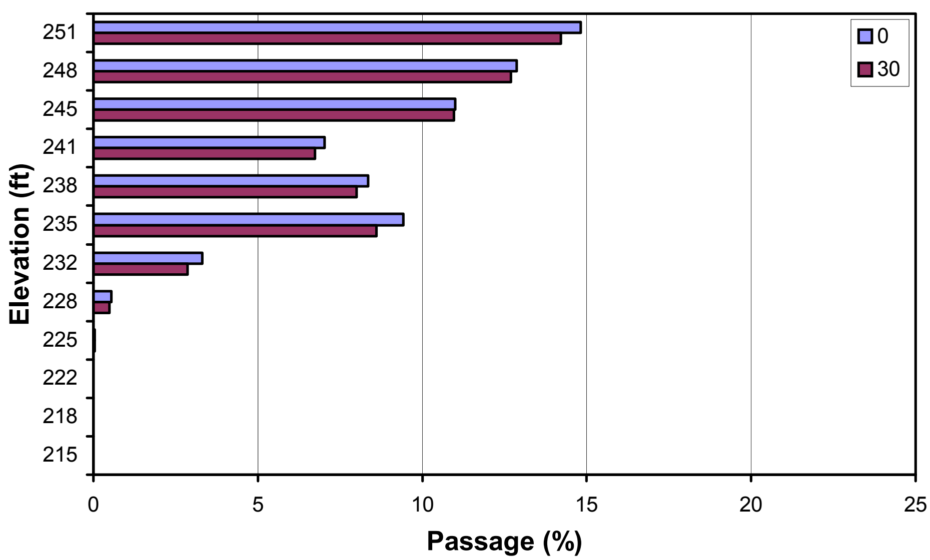


Figure 37. Vertical distribution of passage at the spillway during nighttime by treatment. The crest of the spillway ogee was Elevation 210 ft, and the normal forebay pool elevation was at Elevation 254 ft.

3.5 Horizontal Distributions

Horizontal passage of smolts at the powerhouse was slightly skewed toward the Oregon (south) shore (Figure 38 and Figure 39). This does not appear related to flow because flow patterns are fairly uniform at the powerhouse (Figure 14 and Figure 15). We assume this distribution is related to fish behavior, i.e., subyearling chinook following the Oregon shoreline. In comparison, horizontal distribution at the spillway was highest toward the north shore during 30% spill, and concentrated at Bay 1 during nominal 0% daytime spill since it was the only route of passage available in the vicinity (Figure 40). During nighttime, horizontal distributions were relatively similar among treatments (Figure 41). The horizontal distribution at the spillways is consistent with the distribution of flow (see Figure 12 and Figure 13)

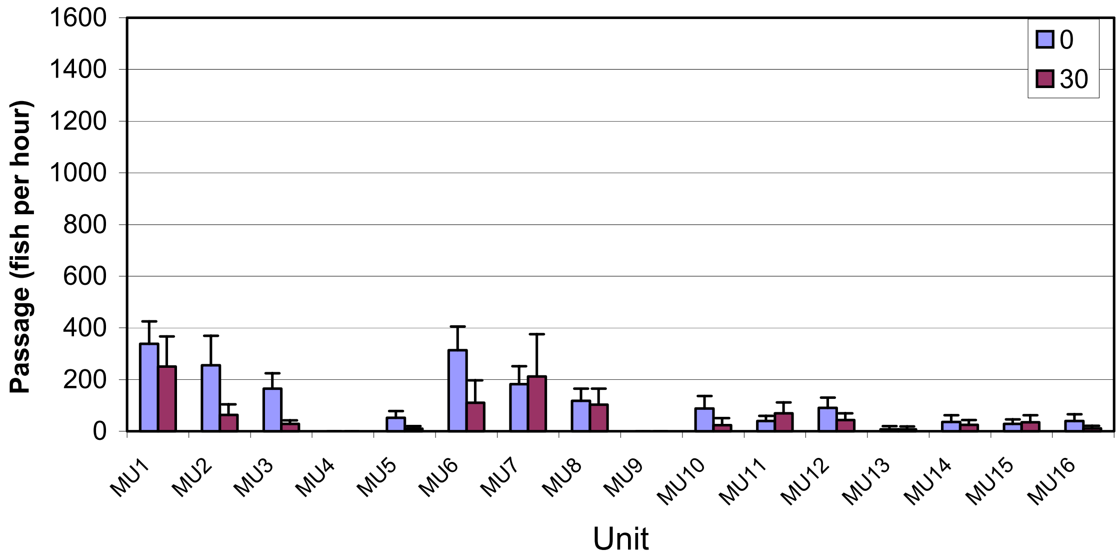


Figure 38. Horizontal distribution of fish passage at the powerhouse during daytime by treatment.

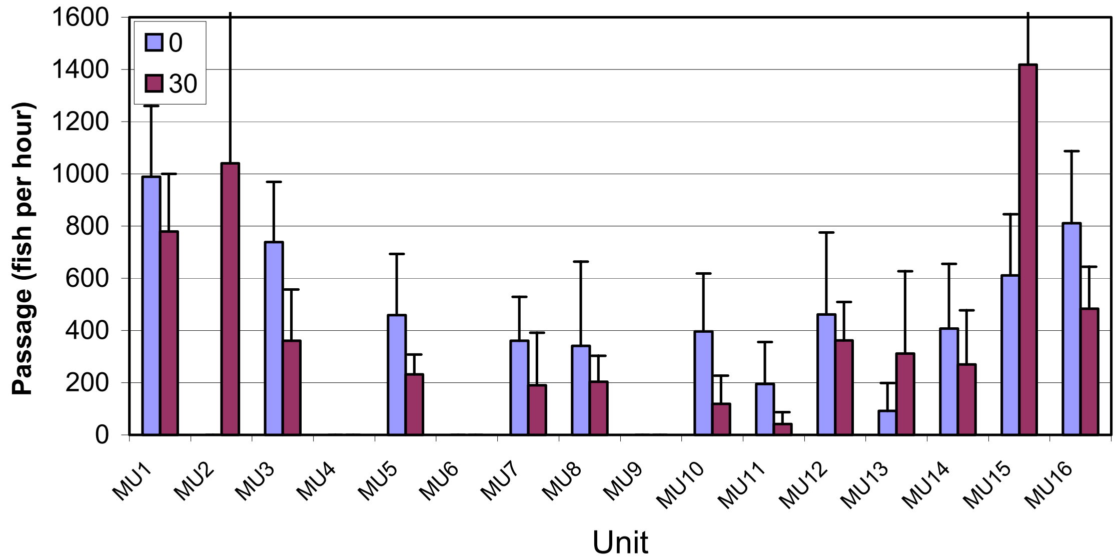


Figure 39. Horizontal distribution of fish passage at the powerhouse during nighttime by treatment.

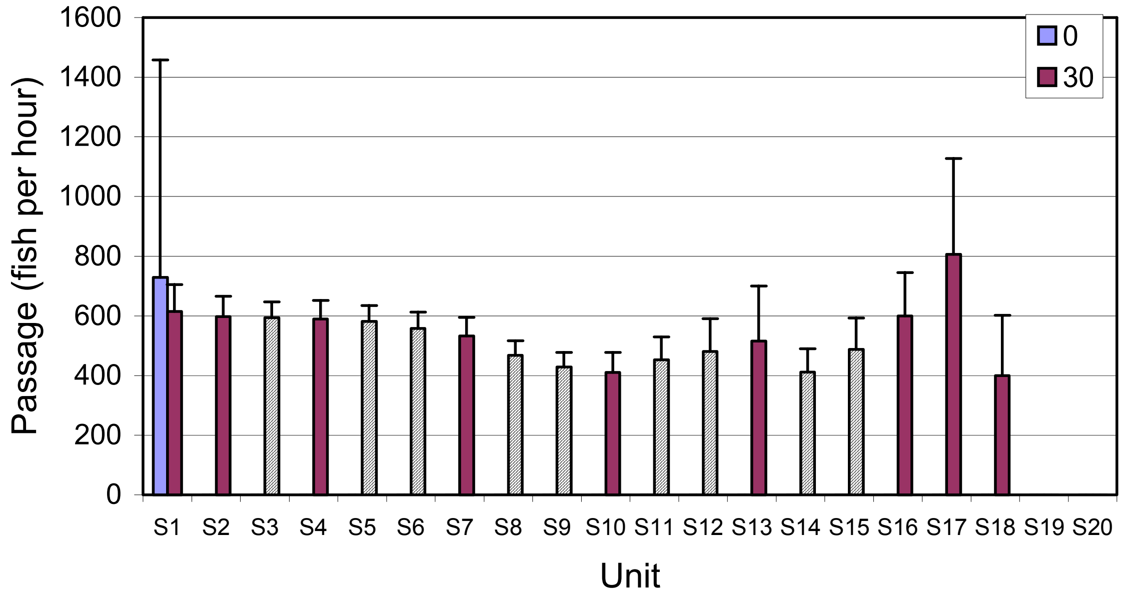


Figure 40. Horizontal distribution of fish passage at the spillway during daytime by treatment. Interpolated values are indicated by hatched bars.

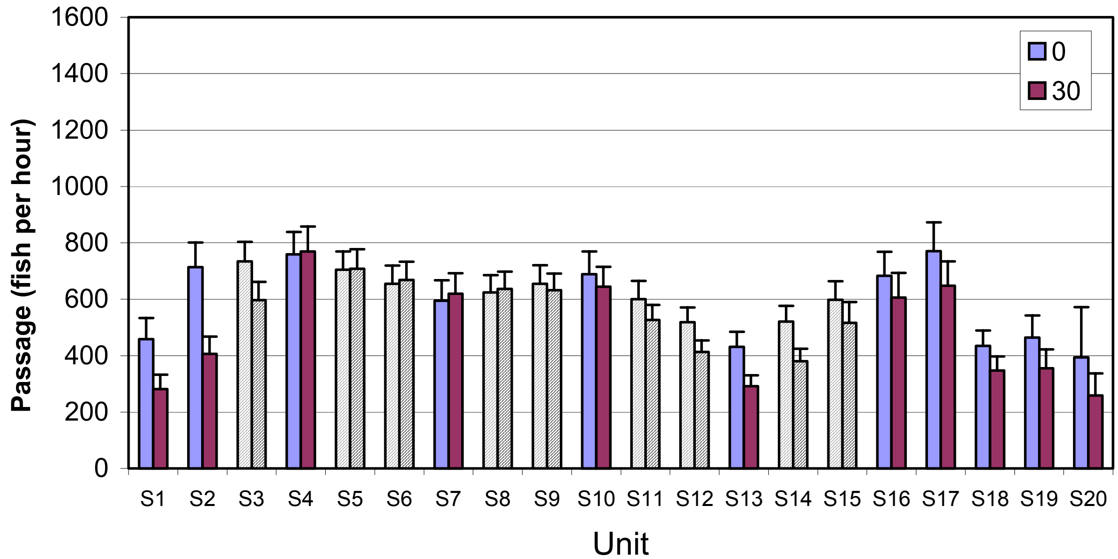


Figure 41. Horizontal distribution of fish passage at the spillway during nighttime by treatment. Interpolated values are indicated by hatched bars.

3.6 Diel Distribution

Diel distribution at the powerhouse peaked at night (Figure 42). A secondary peak was also evident at midday for 0% spill treatment. This peak suggested that when the spillway is closed, or nearly so, more fish pass through the intakes. Diel distribution at the spillway was bimodal with peaks in the morning and evening (Figure 43). These trends are similar to those reported for the 1999 study (Johnston et al. 2000).

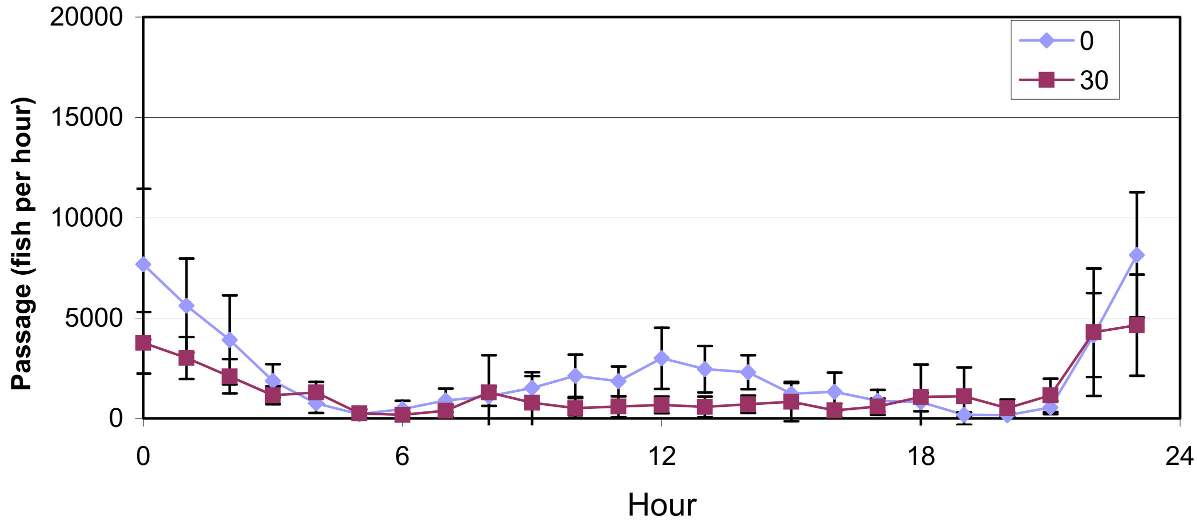


Figure 42. Diel distribution of passage at the powerhouse by 24-hr treatment.

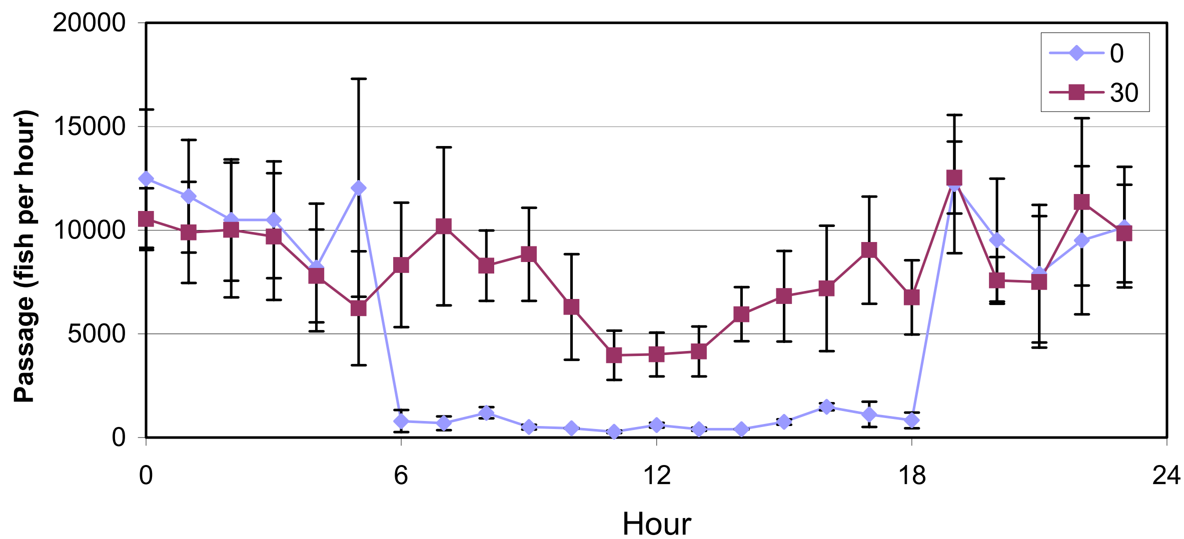


Figure 43. Diel distribution of passage at the spillway by 24-hr treatment.

4.0 Discussion

4.1 Fish Passage Metrics

The majority (92%) of the run at the time of this study was subyearling chinook. Since no subyearling chinook were radio-tagged in 2000, a direct comparison to the concurrent radio tag study is not possible. However, spill effectiveness values from radio-tag studies suggest a range of 1.1 to 3.0. Previous hydroacoustic studies suggest similar or slightly higher values. This study, when combined for the season as a whole, provides an estimate within the range of the radio tag data. However, when the data from this study are examined closer the spill passage metrics appear to be very high. While we do not know if these values are either real or an artifact of the technology, it provides a basis for further investigation.

4.1.1 Treatment Effects

Under all spill treatment conditions, more fish passed per unit water at the spillway than at the powerhouse. Spill efficiency, spill effectiveness and fish passage efficiency were significantly different ($p<0.001$ for both) by spill treatment. Mean spill efficiency was 0.83 for the 30% spill treatment and 0.55 for 0% spill. Mean spill effectiveness was 2.00 for the 30% spill treatment and 27.09 for 0% spill treatment. Mean fish passage efficiency was 0.88 for the 30% spill treatment and 0.67 for 0% spill treatment. Fish guidance efficiency did not differ significantly between treatments. Mean fish guidance efficiency was 0.31 for the 30% spill treatment and 0.27 for 0% spill treatment. The treatments responded as expected. The more water spilled, the higher the proportion of fish passage; the less water through a route, the greater the relative effectiveness. No response of fish guidance efficiency to treatment was detected.

4.1.2 Spatial Passage Patterns

Passage at John Day dam was heavily weighted toward spill. In all spill treatment conditions, more fish passed per unit water at the spill than at the powerhouse. The split-beam data and suspect spill passage when only gate with 1.6 kcfs discharge suggests that the spillway deployment may have been counting individual fish more than once. It is our opinion that the spillway transducers were mounted too far into the forebay from the tainter gate, and thus not all of the fish were committed to passage within the sample volume (transducer deployments are addressed in greater detail in the following Section 4.3). Powerhouse passage was skewed toward the Oregon shore. An overall diagram of fish passage and John Day Dam is shown below (Figure 44).

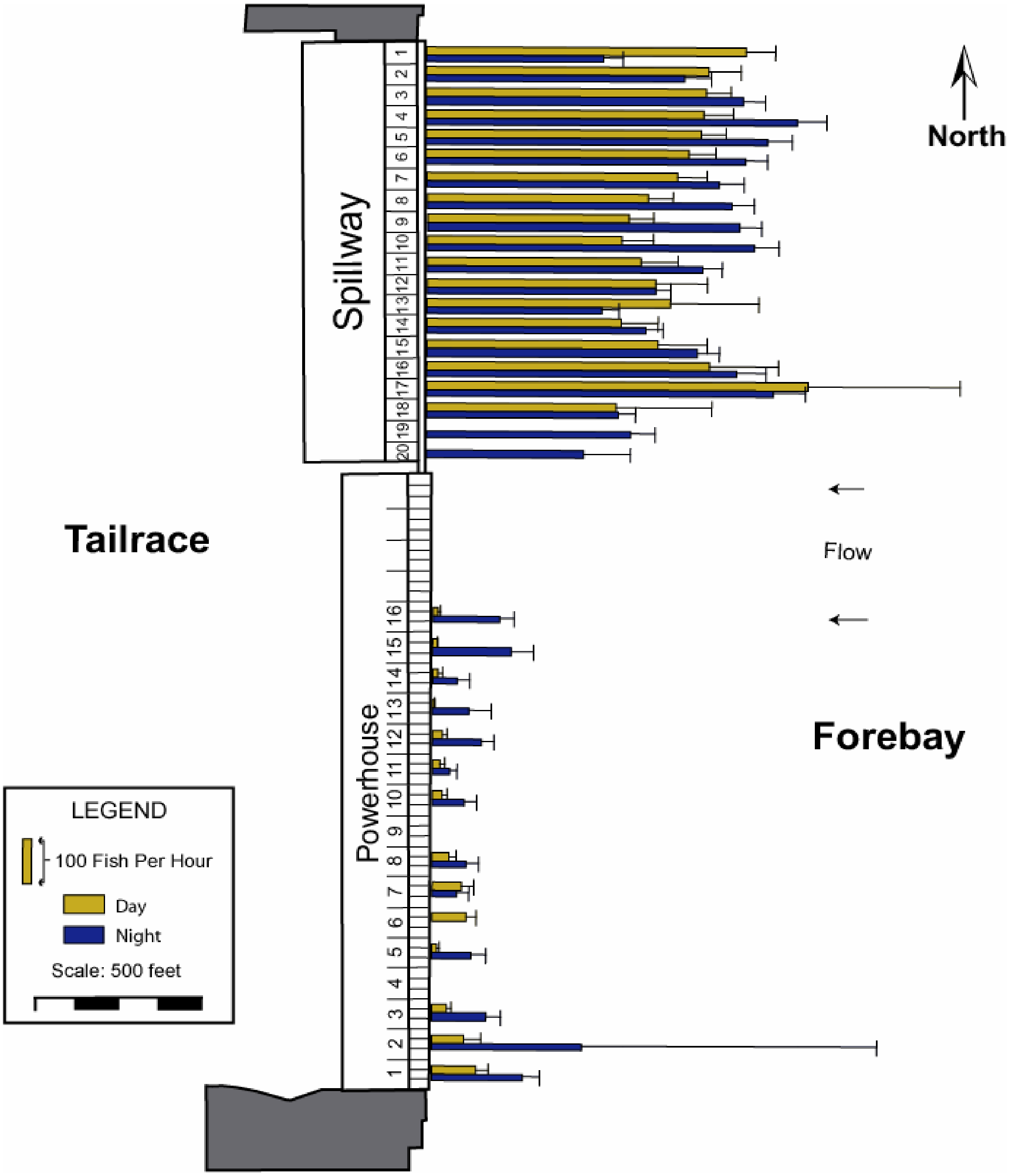


Figure 44. Horizontal distribution of passage at John Day Dam for both treatments, day and night shown separately.

4.1.3 Temporal Passage Patterns

Examination of the diel or horizontal distribution data showed that the several thousand fish that "would have passed" but do not pass during the 0% daytime period are never fully accounted for during the following night or by turbine passage. Either they were holding until the 30% daytime spill or they were undercounted as they passed the turbines (or somewhere). Radio tag data suggests the latter. Cumulative studies have shown that radio tagged subyearling chinook that arrive in the John Day Dam forebay during the day delay passing until night with or without spill (Poe, et al., 2001).

4.2 Hydroacoustic Data Quality and Sources of Error

The methods used in this study closely approximated those used in 1999 by Ploskey et al. (2000). One difference is that wherever possible we used empirically measured data from split-beams as the basis for our detectability modeling. We have found that this method alone is not sufficient in the long run, which can be highlighted with two examples. In the first example, we must know when fish are not detected, i.e. fish that travel through the beam but fall below the ping minimum threshold. These fish are not detected and not accounted for solely by split-beam samples. The second example drawback is the limitation of sample size. When a season of data is subdivided into day/night, spring/summer, spill gate opening, and range, the sample sizes may be too small for reasonable statistical analyses. Each subset of the data alone may not have enough fish samples to adequately describe a mean or a distribution at a given range, thus requiring extrapolation of data. A flow model would provide an independent basis for that extrapolation. Thus detectability modeling, supported by flow data on a spatial scale comparable to the range bins of single-beam transducers, is needed to ensure we are not underestimating non-detected fish and to confirm extrapolated gaps in split-beam data.

Another potential source of error is spatial randomization. Within a limited number of possible spillbays, it is unknown whether the randomization scheme used in this study is sufficient mitigation for potential spatial biases. The magnitude of horizontal uniformity through each spill bay has not been fully tested at John Day Dam. For example, we have not determined whether randomization of transducer placement horizontally is sufficient mitigation at all locations. Quantifying horizontal passage within spillbays would reduce the study's uncertainty.

Quality assurance procedures allowed us to quantify the magnitude of potential sources of error in manual tracking (Appendix B). While this bias can be reduced procedurally (e.g. randomized processing of the data files) it can never be eliminated Autotracking software would eliminate reliance on manual tracking, and thus eliminate one source of error. Standardization of processing methods, both in autotracking and detectability modeling, would reduce uncertainty for multi-year comparisons (Poe, et al., 2000).

4.3 Transducer Deployments

While the results for this study comport well with results from last year, the split beam analysis showed that the spillway deployment was not optimum, i.e., fish within the spillway sampling volume were not necessarily committed to passage. It was apparent that even though the deployment location was moved closer to the tainter gate, it was not close enough. We dealt with this issue by adjusting passage rates based on the ratio of fish that moving toward the spillgate. However, this is not the preferred approach because it increases the uncertainty of the fish passage metrics.

This uncertainty ultimately affects other metrics used for this study. The result is that SPY, SPS, and FPE are more sensitive to the accuracy of split-beam analyses than would be the case if spill deployments included a higher proportion of fish committed to passage. Because split-beam results are necessary inputs for computing passage at all single beam deployments, passage estimates were affected by the adjustments. The fish passage metrics are ratios of several estimates, and though the effect of inaccuracies is less direct it is potentially just as important.

4.3.1 Intakes

Both an uplooking and downlooking transducer were attached to the inside of the trashrack in an attempt to gather data to estimate FGE. Previous hydroacoustic studies have used the uplooking transducer to estimate powerhouse passage. In this study, the uplooking transducer was used to estimate guided fish passage, and the downlooking transducer was used to estimate unguided passage. Even though similar transducer-pair deployments have been used successfully in the past at other dams, the deployment for estimating FGE was poorly situated. Notably, the trashrack-mounted FGE transducer pair was used with reasonable success at John Day Dam in 1997 (Ploskey and Carlson, 1999), but only for an ESBS.

The deployment issue was mainly one of geometry. In order to sample unguided fish using the x-pair method (so called because the beams cross to form a letter "x") the downlooking transducer is canted out until it is aimed just in front of the tip of the screen. When this is done at John Day Dam with an ESBS, the beam remains relatively vertical. Also when this is done at Bonneville Dam's First Powerhouse with an STS, the beam remains relatively vertical. When this is done at John Day Dam with an STS, however, the angle is closer to 45-degrees from vertical. As part of the investigation into why this is so, we compared intake lengths of the lower Columbia River mainstem dams. Based on engineering drawings of the space between the trashrack and the first intersection of the intake roof and gatewell, the intake length of John Day Dam is quite a bit longer than Bonneville Dam's First Powerhouse. Further, the ESBS deployed in the previous hydroacoustic study was approximately twice the length of the standard-length STS, which were used for this study.

Table 13. Intake length comparison.

	Bonneville Dam First Powerhouse	The Dalles Dam	John Day Dam
Intake length	30 ft.	43 ft.	42 ft.

The geometry of the intake, screens, and hydroacoustic beams is critical for detectability. When the beams are vertical, or nearly so, fish pass through the beams at a dorsal aspect relative to the transducer. For this study, the downlooking beam was at nearly the same angle as flow according to physical model data. Thus, whether the fish is oriented with or against flow, the fish will pass through the beam at either a head or tail aspect to the transducer. This aspect is not conducive to the detection of fish (Love, 1977). Ploskey and Carlson, too, noted that detectability even for the x-pair at an ESBS may be very poor near the tip of the screen where fish are oriented along the axis of the transducer and moving fast.

A new intake deployment for future hydroacoustic studies is suggested below (Figure 45). The uplooking transducer would sample the total intake passage in the same manner that it has been used in previous studies. The downlooker would be repositioned to the top of the intake screen, e.g., onto the tubular cross-member and aimed down behind the screen. This transducer, sampling behind the leading edge of the STS, would detect fish that were unguided and committed to turbine passage. This downlooking behind-the-screen type of deployment has been used in other screen studies, e.g., Johnson et al. 1997, and was also recommended for trial at John Day Dam by Ploskey and Carlson. By detecting unguided fish downstream of the screen, a potential bias of fish encountering the lower part of the screen and going below the screen, is avoided. In situ measurements at the ESBS screen face have shown flows at the tip of the screen are directed downward (Weiland and Escher, 2001).

The calculation of FGE from this pair of transducers would be different. The traditional FGE deployment derives FGE in terms of *guided* and *unguided* passage estimates (Equation 5). The proposed deployment derives FGE in a similar manner (Equation 6), but uses the data from *total* and *unguided* transducers. The total estimate would be provided by the uplooker, and the unguided estimate by the downlooker in the configuration below. In both cases *total*, *guided*, and *unguided* represent one transducer each.

$$FGE = \frac{guided}{guided + unguided} \tag{5}$$

$$FGE = \frac{total - unguided}{total} \tag{6}$$

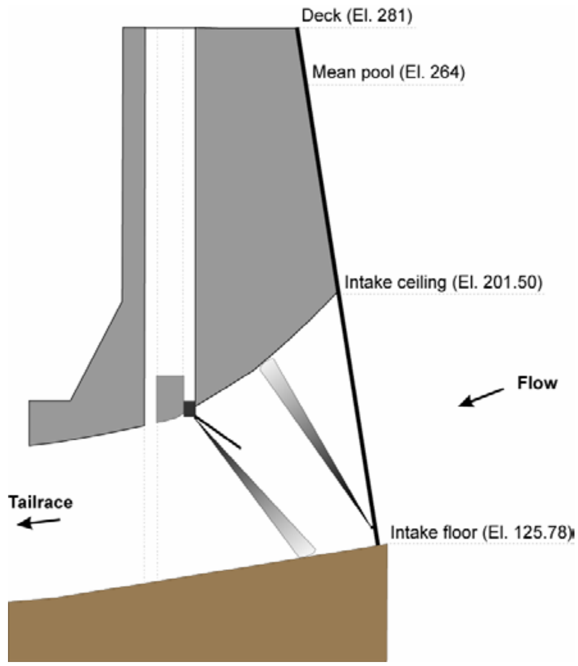


Figure 45. Proposed alternate hydroacoustic deployment for estimating FGE. The total passage would be estimated by the uplooking transducer, farthest right. Unguided passage would be estimated by the downlooking, on the left.

One concern for using this alternate method of calculating FGE was its effect on the variance of the metric. In fact, based on a unit analysis, the variance would be greater for this method. The exact amount of this increase is not known because it is based on the variance of the sensor in a deployment that has not been tested. Appendix E specifically addresses this issue. One other caveat to this deployment is that care must be taken to aim as close to the back of the screen as possible to detect fish passing, unguided, below it. If the aiming angle is not tight to the screen, then potentially milling or swirling fish directly behind the screen may cause multiples counts of unguided fish.

4.3.2 Spillway

Non-commitment of fish through the spillway sampling volumes has already been noted as a bias in this study. This situation resulted in a greater uncertainty in SPY, SPS, and FPE than is apparent solely from the calculated variances. The 1999 study (Johnston, Nealson, and Horchik, 2000) also found fish non-commitment at the spillway deployments. Fish at the spillway split beam location were still surface oriented and with less directionality than the powerhouse deployment. In this study, the spillway mounts were moved back toward the tainter gates in an effort to simulate the spillway deployments at The Dalles Dam (Ploskey, et al., 2000). This would intercept and count fish just as they pass through the spillway, lower in the water column and with a much higher proportion of fish committed to passage at that point. The spillway mounts, as they were deployed in 2000, were inadequate for sampling fish passage at the spillway. Alternate deployment options to locate the transducer sampling volume closer to the tainter gate should be investigated and deployed on a trial basis prior to another full-project study.

5.0 Conclusions

Treatment effects were significant for fish passage efficiency, spill efficiency, and spill effectiveness, but not for FGE. The reduction in FPE during 0% daytime spill was enough to reduce FPE for the 24-hr treatment day, relative to the 30% treatment day. Spill effectiveness values were extremely high and spill efficiencies were low during the daytime of a 0% daytime spill treatment (when only spill bay 1 was open to maintain attraction flows to the adult fishways). Also, 30% daytime spill was more effective at passing fish than the 60% nighttime spill of either treatment. Day/night relationships were confounded with treatment. A different experimental design should be selected to fully evaluate the influence of day versus night on passage.

Analyses of hydroacoustic data indicated that placement of the spillway transducers was not optimum. As a result, there was a high degree of uncertainty in spillway passage estimates. This uncertainty influenced FPE, spill efficiency, and spill effectiveness metrics. Thus, the influence of spill treatments on FGE could not be determined with certainty. The specific inadequacies have since been addressed in detail and this knowledge will be applied to any future studies.

6.0 Recommendations

This investigation has indicated several ways to improve the ability to quantify fish passage at John Day Dam in the future. Spillway transducer sampling volumes should be moved closer to the tainter gate. (Moving the spillway mounts even closer to the tainter gate was planned for 2000, but could not be implemented.) To sample closer to the tainter gate, either new or modified mounts will be needed to sample the spillway. These mounts should be built and tested in one or a few spill bays before conducting another extensive study of spill passage. A horizontally opposed pair of split beam transducers positioned at the elevation of greatest passage could be used to determine whether randomization of transducer placement within monitored spill bays is sufficient mitigation of horizontally non-uniform passage.

The proposed spillway weir is expected to present unique challenges to hydroacoustic sampling. Many new issues can be addressed prior to equipment deployment. A primary tool for this could be computational fluid dynamics modeling (CFD). A CFD could be completed after the engineering design phase, and before the initiation of construction. The modeled flow data would form the basis of modeling detectability at new deployments. The use of the CFD for evaluating equipment deployment and detectability adds value to the investment of creating the models. This potential added-value is not realized if the CFD is created after passage evaluation studies have begun.

A new FGE deployment is recommended to overcome previous deployment limitations. Pilot-scale field-testing prior to full project passage studies would be prudent. Fyke net and hydroacoustic data have been shown to be significantly correlated. Fixed-location hydroacoustics is a nondestructive sampling technique that could be used more extensively than fyke netting. It may be possible to test this new deployment in conjunction with prototype ESBS fyke net tests. This would produce a comparable data set and provide an independent verification of the hydroacoustic estimates of passage.

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